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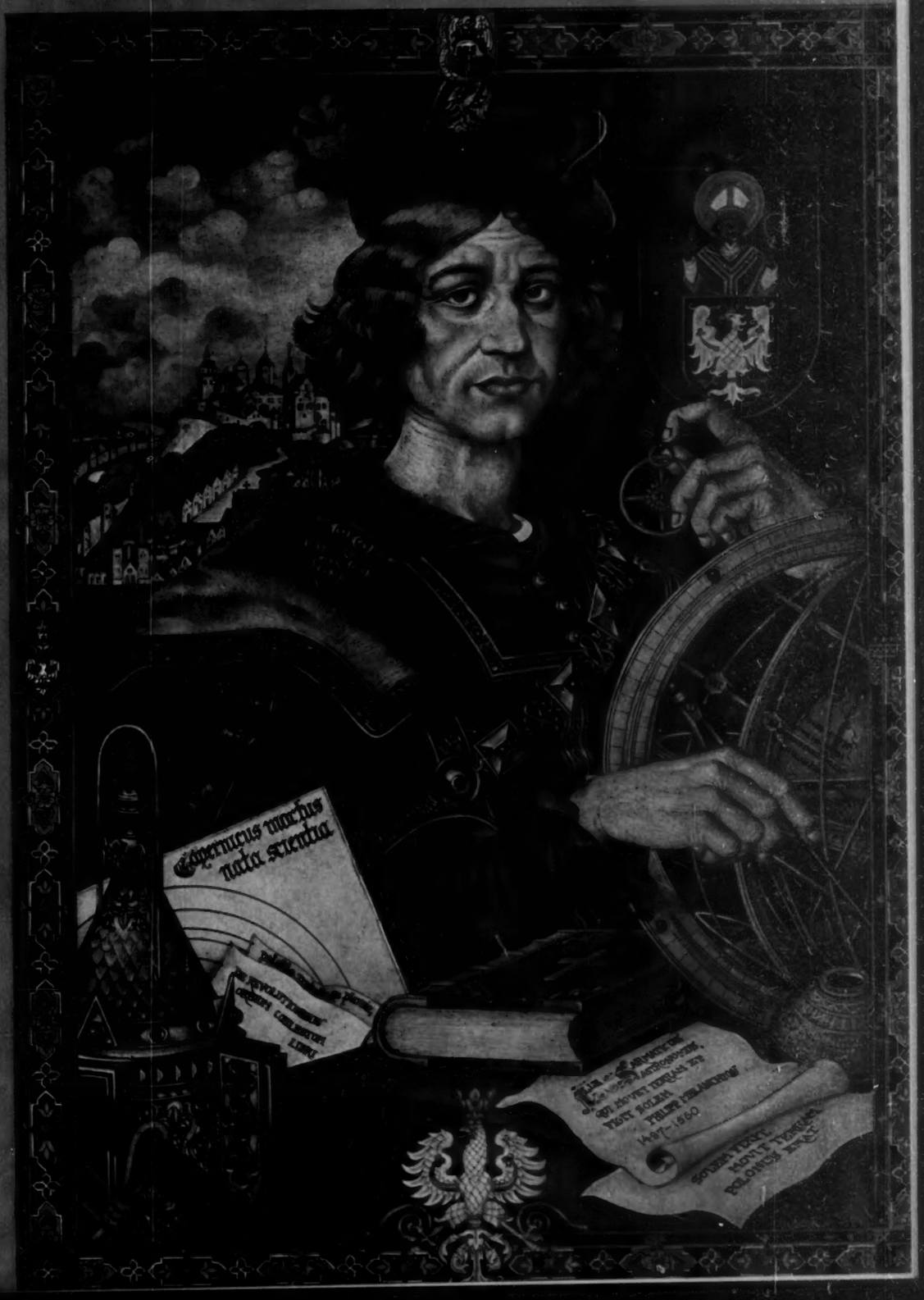
Sky and TELESCOPE



In This Issue:

Nicholas Copernicus—
The Man and His Work

The Case of
the Willamette

A Tribute to Copernicus

Air and Sea and Sky

★

Vol. II, No. 7
MAY, 1943
Whole Number 19
20 cents

★

Nicholas Copernicus
(1473-1543)

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Sky and TELESCOPE

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The Editors Note . . .

THIS month we commemorate the 400th anniversary of the death of Copernicus, thereby paying tribute to a man, an astronomer, and a country. Leader in planning the celebration is the Kosciuszko Foundation, an organization devoted to furthering cultural and intellectual relationships between Poland and the United States.

The multicolored cover design on this issue, portraying the great astronomer, Copernicus, and drawn by Arthur Szyk, has been reproduced through the courtesy of the Kosciuszko Foundation from the same five-color process plates that were used in printing the cover of the little volume, **Nicholas Copernicus, 1543-1943,** by Stephen P. Mizwa, reviewed in **Sky and Telescope** last month.

The artist is a Polish refugee, who has done striking work in caricature and in portraying outstanding Polish and American personalities. As described in the book, the cover shows Copernicus as churchman, scholar, and astronomer. The chain and cap are academic symbols. In his left hand he holds a device illustrating the Copernican theory, with the sun at the center of the solar system. In front of him is an enlarged fragment of the Jagiellonian golden globe.

In the upper left-hand corner is Wawel, the Polish Acropolis, with the center of Kraków as it looked in Copernicus' student days (1491-95). The coat-of-arms of the University of Kraków appears at the upper right, with the Roman numbers (1364-1400) indicating the years when the University was founded and renovated, respectively. On the table is the Holy Bible. The lantern is such as he used on his observation tower at night.

The lower border bears the Polish white eagle of the Jagiellonian period (red and white are Polish national colors). On the other borders are the coats-of-arms of Gniezno, first capital of Poland (left), of Kraków, capital of Poland in the astronomer's student days (right), of Torun, Copernicus' native city (top).

Highlight of Copernican celebration activities will be the meeting in Carnegie Hall, New York City, on May 24th. His Excellency, Jan Ciechanowski, ambassador of the Republic of Poland to the United States, will take part, and many of our foremost American astronomers are scheduled to speak. Dr. Harlow Shapley, national chairman of the Copernican Quadricentennial Committee, will preside. Information regarding this meeting may be obtained from the Kosciuszko Foundation, 149 East 67th Street, New York City.

On the occasion of the quadricentennial, the Foundation will begin its preliminary and preparatory work toward the post-war educational reconstruction of Poland, especially toward rehabilitation of the destroyed university libraries. The Foundation hopes that "thus, the commemoration of a great Polish scientist of distant past may become a call to the living to pass on a torch of light to those of the future."

Among the books on cultural topics pertaining to both countries which the Foundation has been instrumental in publishing is the one from which our front cover is reproduced. This book is available from the Foundation in a popular edition, pamphlet bound, at 75 cents, and in a cloth cover at $1.50. A limited number of prints of the color cover, on heavy 11x14 paper, are available at $1.00 each.

There has been wide interest in the book and its contents. The **Journal** of the Royal Astronomical Society of Canada says: "Filled with authoritative facts and adorned with numerous reproductions of rare portraits and historic scenes . . . the valuable publication is recommended to the many friends of Poland and of astronomy." Otis Peabody Swift, of **Time,** has written: "A perfectly magnificent volume on Copernicus. I have seldom seen a better done brochure." And the editor of **Scripta Mathematica,** Jekuthiel Ginsburg, writes: "It is beautiful in form and in spirit and it will form a must addition to the Library of any scholar interested in the life of Copernicus and the history of Mathematics and Astronomy. It is a most dignified tribute to the memory of the great Polish astronomer."

On behalf of our readers, we gratefully acknowledge the magnificent cooperation of the Kosciuszko Foundation in so generously providing the plates and assisting in the arrangements for printing the beautiful cover of this Copernican issue of **Sky and Telescope.**

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Nicholas Copernicus on the observation tower at the Cathedral of Frauenberg, by Jan Matejko (1838-93), the Polish national painter. Courtesy, the Kosciuszko Foundation.

NICHOLAS COPERNICUS

The Man and His Work

BY EDWARD ROSEN

College of the City of New York

IN MAY, 1943, the entire civilized world commemorates the passing away 400 years ago of the man who reversed the direction which astronomy had taken from the earliest times. By shattering the naive and common-sense notion that the earth is an inert, stationary mass, and by demonstrating that, on the contrary, the earth is a planet in motion, Nicholas Copernicus initiated the modern phase in the development of the science of the heavens.

Twenty years after the Turks brought the Byzantine Empire to an end by their capture of Constantinople in 1453, the child was born who was destined to overthrow the astronomical system that had held sway even longer than the 1,000-year-old Byzantine Empire. In the flourishing merchant city of Thorn, or Torun, on the banks of the Vistula River in northeastern Europe, in the heart of a fertile agricultural region, the founder of modern astronomy first saw the light of day in 1473.

About his infancy and childhood we know practically nothing, except that when he was only 10 years old, his father died. The loss of this parent, who had been a prosperous businessman and a municipal official, might have been a severe blow. But his mother's brother had entered the service of the church, and in the course of the years rose to be head of the virtually autonomous bishopric of Ermland or Varmia in Polish Prussia. The bishop, whose name was Lucas Watzelrode, took a fatherly interest in his nephew, watching over him carefully and smoothing his path.

In fact, the career which Nicholas adopted followed in the footsteps of his maternal uncle. Thus, when he was ready to begin his higher education, he entered the University of Kraków at the age of 18. Like his uncle before him, for several years he studied the liberal arts at that renowned Polish institution, then the foremost school of Eastern Europe. But upon his return home he was sent across the Alps, where he spent the next decade (1496-1505) at various Italian universities. Lucas Watzelrode had also gone to Italy as a young man; by a coincidence he received the doctoral degree in law from Bologna University in the very year in which Copernicus was born. Lucas had gone on to become a canon of Frauenburg, a town in the Ermland diocese that was situated on the coast of the Baltic Sea; and after his elevation to the rank of bishop, he procured his nephew's appointment in 1497 as a canon in the very chapter to which he had belonged. In these three important respects, then, the outward life of Copernicus was patterned after his uncle's: undergraduate study at Kraków, graduate work in Italy, and ecclesiastical service as a canon.

This church office carried an assured annual income for life. But a heavy part of the price that had to be paid for such enviable security in a turbulent and unsettled society was the vow of celibacy, a promise never to marry. It is sometimes erroneously stated that Copernicus became a priest; but as a matter of fact he never took holy orders. On the other hand, he was no monk, either; for he never joined any of the regular monastic brotherhoods.

The canons attached to a specific church were organized in a body known as a cathedral chapter, through which they administered their affairs. From the cathedral chapter of Frauenburg Copernicus sought and obtained leave of absence to continue his studies at the famous Italian universities. Those were the years when Italy was the intellectual center of Europe. Students were attracted to it from far and wide. Floods

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BACK COVER: Two pieces of the Willamette (from the collection of Mr. and Mrs. J. Hugh Pruett) which were taken from different parts of the meteorite, show different types of etching. (See page 6.)

When Napoleon visited Torun, Copernicus' birthplace, in 1807, he was surprised that no monument had been erected to honor the astronomer. Courtesy, the Kosciuszko Foundation.

of excellently printed books poured from its busy presses. Brilliant works of art were executed by architects, sculptors, and painters of high talent. From neighboring lands momentous voyages of discovery were conducted both eastward and westward, across the vast Indian Ocean to the Far East and over the uncharted Atlantic to the New World. A lively and contagious curiosity inflamed men's minds. The stirring achievements of Columbus and da Gama, da Vinci and Michelangelo, contributed to the formation of a new intellectual climate, the Renaissance.

In this invigorating atmosphere Copernicus spent 10 fruitful years. He had promised to make himself more useful to his chapter by mastering medicine. But although he attended the universities of Bologna, Padua, and Ferrara, listening to lectures on the healing art and on law, his first love was the study of the heavens. His earliest recorded observation was performed at Bologna in 1497; and from that time forth he remained a persistent watcher of the skies. He evidently made something of a reputation as an astronomer, for in the jubilee year of 1500 he was invited to deliver a lecture at Rome before a large audience of students and specialists in the science. Having enjoyed a full decade of intimate contact with humanist culture, and having earned a diploma as Doctor of Both Laws, that is, both canon law and civil law, Copernicus made the long trip home to take up his duties as a canon.

Now that his prolonged student days were over, his first assignment was the congenial task of living at the residence of his uncle, Bishop Lucas, in the interior of the diocese. His functions were to assist the bishop and guard his health. Six quiet and productive years ensued, during which Copernicus' first publication appeared. While he had been in Italy, the well-known Aldine Press in Venice had issued a collection of Greek letters. From this volume he selected the epistles of a Byzantine historian and, translating them into Latin, had them printed at Kraków, at that time the capital of the kingdom of Poland. He dedicated the slender work to his uncle, the bishop. This little linguistic exercise, curiously enough, was the only thing written by Copernicus, to the printing of which he attended personally. Only two of his other writings, the *Trigonometry* and the *Revolutions,* went to press during his lifetime, and in each case the manuscript was simply put into the hands of friends by the astronomer, who was already well along in years. All his other papers were first printed in relatively recent times.

Early in 1512, Bishop Lucas set out for Kraków to attend the wedding of the king of Poland. From that ill-fated journey he never returned. After the death of his uncle, Copernicus proceeded to Frauenburg, the seat of the cathedral chapter, where he spent the next four years.

While he was in his forties and therefore still in full possession of his physical vigor, he was charged with the arduous responsibility of administering the outlying landed estates owned in common by the chapter. In 1520, armed bands of Teutonic Knights, with the support of troops drawn from Germany, invaded the peaceful villages of Ermland, burning, pillaging, destroying, and killing. Frauenburg, too, got its taste of the *furor Teutonicus* or *Schrecklichkeit.* Artillery and emergency provisions were rushed to Copernicus, who was in command of the fortress of Allenstein or Olsztyn, "this bulwark of our entire diocese," as one of his colleagues called it.

One of the consequences of the war was an acute financial crisis. His experience as an administrator had inevitably brought the money question to Copernicus' attention, and he had formulated some theoretical principles and practical suggestions for dealing with a depreciated currency. After the Teutonic Knights were repulsed and peace was restored, his statesmanlike proposals were set forth at an assembly of the Prussian Diet, which he attended as a delegate of his chapter. His presentation was valued so highly that he was repeatedly sent to subsequent meetings as personal representative of his bishop. Although certain of his recommendations were incorporated in a currency decree issued by the Polish crown, the clash of conflicting selfish interests blocked a completely satisfactory treatment of the situation.

A fellow canon complained to Copernicus that his essay on currency reform was somewhat obscure. Copernicus began his reply with the following remarks: "It is of no small importance to be able to throw light on matters that by their very nature are wrapped in thick fog. But it is also possible for a man who perceives the truth to be unable to express it. This, I fear, sometimes happens to me." And he closed his discussion of the topic with this comment: "I acknowledge that I may be wrong. I am only one man, and I have only one mind, and I am unaware or ignorant of what others regard as more useful proposals."

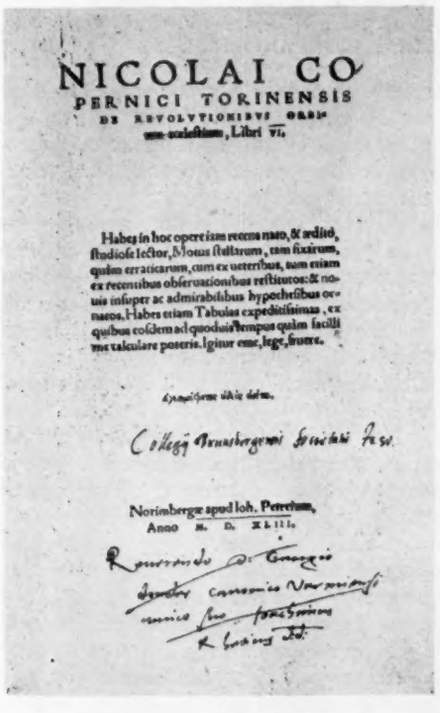
By this time Copernicus was approaching his 60th year, and administrative and ambassadorial functions were regularly assigned to his more youthful colleagues. Freed from these onerous burdens, he could devote a greater proportion of his time and energy to the dominating interest of his life, the study of astronomy. In particular, he concerned himself with the perplexing problem of correcting the calendar. The western world was still operating under the calendar that had been promulgated by Julius Caesar; and it was widely recognized that the defects of the Julian calendar urgently needed repair. "Not so long ago," Copernicus tells us in the preface to his *Revolutions,* "under Leo X the Lateran Council considered the question of reforming the ecclesiastical calendar. The problem remained unresolved then only because it was felt that the lengths of the year and month and the motions of the sun and moon had not yet been adequately measured. From that time on . . . I directed my attention to a close study of these topics." Continued efforts at reform throughout the 16th century culminated in the replacement of the Julian calendar by the Gregorian, which regulates our lives today. The Gregorian calendar, instituted in 1582, was to a considerable extent based upon Copernicus' computations and conclusions.

In observing the heavens he suffered from a severe handicap. Attention to his duties forced him to do most of his

stargazing at Frauenburg, which was not the most suitable location in the world for an observatory. With manifest envy he tells us in the *Revolutions* that "the ancient observers had the benefit of a clearer atmosphere, for they say that the Nile does not give rise to fogs, such as we get from the Vistula. Nature has denied that advantage to us, the inhabitants of a more rigorous climate, where fair skies are rare and the high latitude permits Mercury to be seen only infrequently." From this passage it is evident that there is no basis for the statement sometimes encountered that Copernicus never laid eyes on the planet Mercury.

Although the difficulties imposed by a harsh natural environment were undoubtedly serious, they were not as important as they might be to a modern astronomer, who must often make unremitting observation of the same body night after night. It was customary in Copernicus' time to make crucial, rather than continual, observations. When an effort was being made, for example, to determine one element of a planetary orbit, the planet would be observed and careful measurements taken on several successive nights, and then not again, perhaps, for a considerable interval. When we think of Copernicus as an observer, we must of course bear in mind that he did his work during the period of naked-eye observations, since the telescope was not introduced until some 60-odd years after his death.

The story of the closing years of his life and the publication of his theory has already been sketched in The SKY, September, 1940; abstracts of this note are appended here.[1] We turn our attention to what is without doubt the most significant aspect of his immortal treatise, *On the Revolutions of the Celestial Spheres*. Early in his career Copernicus became convinced that the prevailing system of astronomy was fundamentally unsound. For almost 14 centuries the views of Ptolemy had reigned supreme. Although minor trends did develop in other directions, in all that time no one had ever successfully challenged the Greco-Roman astronomer of Alexandria.

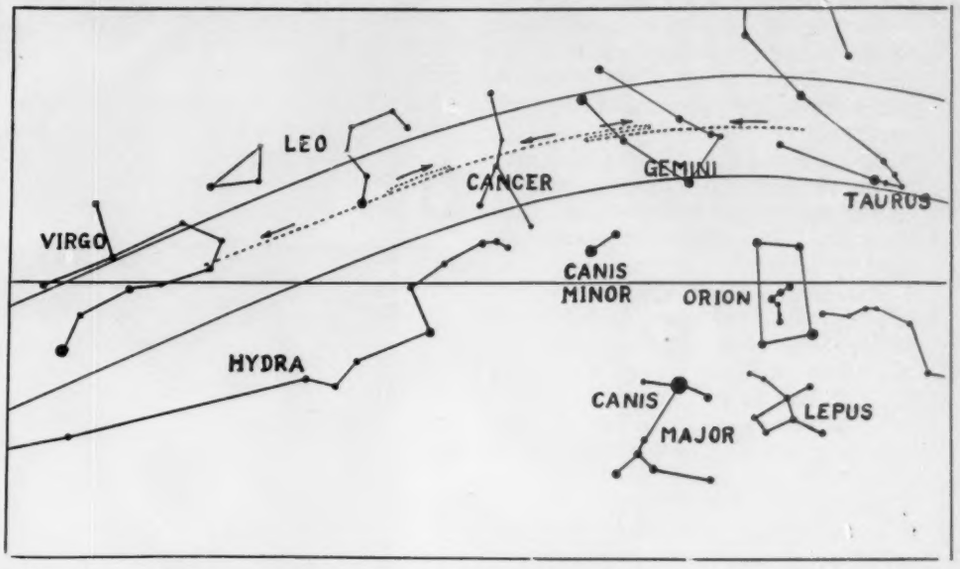

NICOLAI CO
PERNICI TORINENSIS
DE REVOLVTIONIBVS ORBI
um cœlestium, Libri VI.

Habes in hoc opere iam recens nato, & ardité, studiose lector, Motus stellarum, tam fixarum, quàm erraticarum, cum ex ueteribus, tum etiam ex recentibus obseruationibus restitutos: & nouis insuper ac admirabilibus hypothesibus ornatos. Habes etiam Tabulas expeditissimas, ex quibus eosdem ad quoduis tempus quàm facillime calculare poteris. Igitur eme, lege, fruere.

Collegij Brunsbergensis Societatis Jesu

Norimbergæ apud Ioh. Petreium,
Anno M. D. XLIII.

The title page of "De Revolutionibus" (first edition). This copy of the book was apparently donated to the Jesuit College of Brunsberg, in Varmia. Courtesy, the Kosciuszko Foundation.



This chart of the apparent motion of Jupiter from 1942 to 1945 illustrates the annual retrograde movement which the ancients found so difficult to explain, but which presents no problem at all to the Copernican theory.

In the Ptolemaic system the earth was regarded as stationary. Therefore it was firmly believed that the sun really rose each morning in the east, climbed overhead, and set in the west. For this account of the situation, which seems to be solidly based on the plain testimony of our senses, Copernicus simply substituted a daily rotation of the earth.

In a similar way, the traditional doctrine held that the planets, moving eastward most of the time, annually slowed down until they actually came to a halt, then reversed themselves and traveled westward for a brief period (retrograde motion), stopped and reversed themselves a second time, resuming their eastward journey, and repeating this cycle of changes endlessly. But Copernicus assigned to the earth an annual orbit about the sun. According to his version of the matter, we view the entire heavenly ballet from a huge observatory, the earth, that is itself in motion. The planetary movements which astronomers trace so carefully are in fact compounded of two ingredients, the real motion of the planets and the real motion of the earth. The annual revolution of the earth about the sun is reflected in the observed movements of the other members of the solar system. The planets do not really reverse the direction of their motion; their motion is always directed in the same sense at a nearly constant rate.

By establishing the fact that the earth is a moving planet and by introducing the concept of relative motion in the interpretation of the heavenly scene, Copernicus overthrew the Ptolemaic system and laid the foundations of modern astronomy. Great as this accomplishment was, it must not be exaggerated. For one thing, Copernicus still clung to the traditional belief that the path of a heavenly body must be a circle or a combination of circles. The discovery that the orbits are elliptical had to wait for Kepler. Again, Copernicus never seriously investigated the causes of planetary motion. He traced the path, but neglected the force. In short, he dealt with the geometry but not with the physics of celestial motion. That gap was closed by the genius of Isaac Newton.

Yet if we look with steady gaze down the long vista of time and visualize the growth of astronomical thought from its groping beginnings to the present day, do we not justly feel a deep debt of gratitude to the destroyer of outworn orthodoxies, the builder of the heliocentric system, the founder of modern astronomy, Nicholas Copernicus?

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[1] **Abstracts from "The Copernican Theory — How it was first presented to the world,"** by Edward Rosen.

IN 1540 there appeared the first printed exposition of Copernicus' heliocentric system. The book was written by an enthusiastic young man, George Joachim Rheticus, who gave up a teaching job in a German university in order to visit the celebrated astronomer and master the new system at its source.

(*Continued on page 14*)

THE CASE OF THE WILLAMETTE

By J. Hugh Pruett, *University of Oregon*

"METEORITES, though not imbedded in the earth, are real estate, and consequently belong to the owner of the land on which they are found. . . . Seeing there is no error in the record, the judgment of the circuit court will be affirmed."

Speaking was Chief Justice Wolverton of the supreme court of Oregon in the case of the Oregon Iron and Steel Company vs. Ellis Hughes; the date was July 17, 1905.

Three years earlier on a wooded hillside (property of the plaintiff) near Willamette, Ore., the defendant had discovered a curious mass of metal — almost 16 tons of it. Later he moved it onto his own land. When the real nature of this find became known, the plaintiff brought suit to recover and won a decision in the lower court. The defendant appealed to the higher court, but was there finally forced to abandon his claims to the huge chunk of nickel-iron which was later famous as the Willamette meteorite, the largest object of its kind ever found throughout the vast expanse of the United States and Canada.

To the day of his sudden death, December 3, 1942, at the age of 83, Mr. Hughes considered this decision an inglorious and unjust defeat. This sturdy, intelligent Welsh woodsman, who lived his last 50 years less than a mile from the spot of the Willamette's discovery, probably never realized that his lasting honor in scientific circles far overbalanced the loss of the mere material possession of the meteorite.

In July, 1938, a party from the University of Oregon visited the scene of discovery, interviewed Mr. Hughes and others familiar with the early history of the event, and obtained many valuable photographs. At that time Mr. Hughes seemed in good health, and very graciously told Betty Jane Thompson, the journalist of the visiting group, many details not found in earlier published accounts.

"I was coming home," said Mr. Hughes, "from where I had been cutting wood for the Willamette school. I noticed this big rock for the first time but didn't think anything of it. The next day I saw a very rusty broken saw near it. I sat down on the rock which was very flat and about 18 inches above ground. Bill Dale came along.

"Then I picked up a white stone and started to hammer on the rock. It rang like a bell. Dale said he bet it was a meteor. It would probably be there yet, but my wife — you know how women are — had ideas. She was afraid somebody would go up and get it the next day."

After months of urging by his wife, Mr. Hughes went to work on a crude truck with which to move the huge mass to a spot near his house three quarters of a mile away. He trusted no one to help him aside from his wife, his 15-year-old boy, and his horse. He made the truck of logs and mounted it on ungainly wheels sawed from a tree trunk. Long and tiring work with levers and blocking was required to get the object elevated above the ground level. Finally, when it was sufficiently raised, the meteorite flopped over and tumbled onto the truck flat side down. Mr. Hughes thrilled at the fond remembrance. "It couldn't have been done better if you'd laid it there with your own hands."

The Willamette meteorite, as it appeared while Mr. Hughes was transporting it through the woods on a truck with wheels made from a tree trunk. The nose of the meteorite is upward. Engraving from the "American Museum Journal."

Mr. Hughes next set up a "Spanish windlass" which he securely anchored with a chain. One end of a 100-foot cable of braided wire connected with the truck; the other wound on the barrel of the windlass as his horse walked in a circle around it. Thus a relatively small force exerted by the horse resulted in an immense pull on the cable.

Then began the long haul. The ground was soft, and board tracks had to be laid and relaid. The windlass had to be moved and re-anchored each time the 100-foot cable was wound on it. So great were the difficulties that some days the truck was scarcely moved more than its own length.

During the process of moving, a neighbor chanced by. The next day a newspaper reporter from the Portland *Oregonian* appeared, but found the meteorite covered with burlap. He insisted on a view of the object, but the covering was not removed. Mr. Hughes said with a twinkle in his eye, "When he asked why I wouldn't, I explained the sun might warp it."

After three months of hard work in the forest, during which time few outside the Hughes family knew what was taking place, the meteorite reached its desired destination. When it was at last safely housed in a wooden building on the Hughes property, it was put on display for an admission fee of 25 cents. People from far and near flocked to see the curiosity.

As luck would have it, among those who paid admission was a lawyer from the company on whose property the meteorite was found. "He offered me $50 for the whole piece," said Mr. Hughes, "and said he wanted to show it at the Buffalo World's Fair. I wouldn't listen to him."

Not long after the attorney's visit, suit was filed by the landowners for possession of the meteorite. Public sympathy throughout the trial was generally with Mr. Hughes. The defense advanced the claim that the mass had originally been the property of the Clackamas Indians, had finally been abandoned by them at the spot where found in 1902, and therefore was not necessarily part of the land. Two old Indians, one of the Wasco tribe and the other a Klikitat, appeared in court in substantiation of this claim. Their testimony ran as follows:

The meteorite, Tomanowos, had orig-

inally fallen from the moon and was thought to possess magical powers. It was held in high regard by the Indians. Rain collecting in its hollows was considered "holy water," and into this the Clackamas tribe dipped their arrows before going to war. Their young warriors were initiated by being compelled on the darkest of nights to climb the hill and visit the lonely spot where the celestial visitor reposed.

The account of a somewhat similar litigation was well aired in court by the plaintiff. This was the case of the Winnebago meteorite in Iowa. The tenant on the property saw the meteorite fall — it was comparatively small — and bury itself three feet deep. The next day he dug it up and assumed ownership. Later he sold it. The landowner brought suit and after several years the court granted possession on the ground that such objects belong to the "owner of the soil upon which they fall."

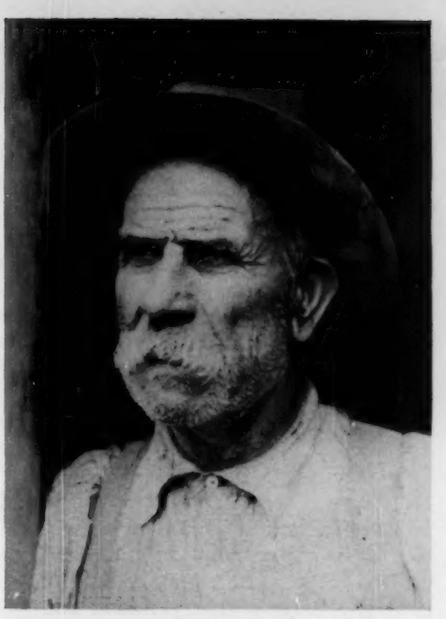
The defense, however, held that there was a marked distinction between the Iowa and Oregon cases. In the former, both sides agreed on the place of fall; in the latter, no one knew where the body had originally landed. The Indians might have moved the meteorite from some other spot in order to give it a place of prominence on the hill. Or, in prehistoric times when water covered the Pacific slope, the metallic mass, together with granite boulders lying near it, might have floated from a distant region on an ice floe. In the language of geologists, it would thus be an erratic, similar to many large granite masses now found in fields and other places where they do not seem to belong.

Finally the circuit court granted possession to the Oregon Iron and Steel Company. The latter soon hauled the contested object from the Hughes property, but got no farther down the road than the Johnson house when Mr. Hughes' appeal to the supreme court stopped further movement. Mr. Johnson, father of Harold Johnson, who still resides in the same locality, was then appointed to guard the meteorite against removal or theft of any parts of it.

Harold Johnson tells that during the many months the mass remained there, the family's sleep was often disturbed by souvenir hunters.

"Today with acetylene torches it might be an easy matter to cut a piece without much disturbance, but in those days the only tools were saws and hammers, and the meteorite would ring like a bell when struck. Often in the middle of the night the 'bell' would clang. Then out of bed jumped father, grabbed his gun and, muttering to himself, rushed outside to start the intruder on his way. I still have a small chunk which father took from a fellow who almost got away with it."

Before the meteorite was placed under guard, small specimens were cut off by various persons. At the request of the National Museum in Washington, Dr. A. W. Miller, Oregon geologist, inspected the huge mass. In a subsequent article, in the Portland *Oregonian* of June 2, 1912, he described his study of the celestial visitor and mentioned that he removed several pieces. Dr. Henry A. Ward, Rochester scientist, made a trip across the continent to study the object. He also obtained several specimens.



Ellis Hughes, discoverer of the Willamette meteorite, as he appeared in 1938. Photo by David Hunter.

At last came the 3,000-word decision of the Oregon supreme court in which the lower court was upheld. After this, the Willamette was taken by water to Portland. From the river it was hauled by 12 powerful horses to the Lewis and Clark Exposition grounds where it was exhibited during the few weeks remaining of this fair.

Scientifically minded Oregonians hoped that this interesting meteorite might remain in the state. But a very tempting bid came from Mrs. William Dodge II, of New York, to whom it was sold on February 15, 1906. Mrs. Dodge presented it to the American Museum of Natural History of New York. It was delivered to this museum April 14, 1906, and placed on exhibition June 7th of the same year. One condition prescribed by the donor was that the main mass should be kept intact in one piece. This weighs 31,107 pounds according to the museum catalogue. In addition, the museum has four other pieces which were evidently removed before Mrs. Dodge's purchase.

In June, 1938, the American Museum, through the kindness of Dr. Clyde Fisher, sent to the University of Oregon on an open exchange a beautiful etched slab of the Willamette, "in order that your school may have a part of the great meteorite found in your state." In addition to this, small specimens are owned by various Oregon residents related to the Hughes and Johnson families and through purchase from them in the past.

Harold Johnson reports that several residents around Willamette who think they have pieces of the meteorite are badly mistaken. The children of the families most closely connected with the historic object were often asked for specimens by their schoolmates. Finding themselves receiving considerable attention, these children obtained pieces of slag from a smelter and passed them out to the unsuspecting who have since cherished them as genuine.

It is generally known that when etched with nitric acid the polished surfaces of pieces from various parts of the Willamette show two distinct types of crystalline figures. The meteorite is classed as a medium octahedrite. Parts of it etch in the long bands characteristic of this class; other parts present a sort of crazy-quilt pattern. Some people assume that this is due to the way the crystals have been cut: crosswise or lengthwise with the grain, but several authorities, including Dr. H. H. Nininger, believe the meteorite has crystallized differently in different places. John D. Buddhue offers this:

"If the direction of cutting were the explanation, I should expect the same structure in other meteorites. The only thing I know of that resembles it at all is the Murn Peowie meteorite from South Australia."

The two different types of etching are well illustrated by the back-cover picture this month, which shows two pieces in the author's collection which were taken from different parts of the meteorite.

The composition of the Willamette is approximately 92 per cent iron and eight per cent nickel. There is disagreement among scientists as to the origin of some of the holes in it, especially those on the rounded side. The cause of the immense cups on the flat side, uppermost when found, is pretty well agreed upon, however. It is thought that mineral matter softer than the main mass originally filled these cavities, but was gradually weathered out during the centuries the meteorite lay on the ground.

When the University of Oregon party visited the Willamette vicinity in 1938, great courtesy was shown the members by the owner of the discovery site, H. S. Crocker, who was operating a fox farm there. The depression from which the meteorite was taken is quite evident. In this hole several pieces of the original underlying rust were found still intact. These contain abundant nickel.

Although our university has only a small slab of the real meteorite, it does, however, have on display on the campus a "life-size" plaster model of the Willamette. This has such a surface finish and color that many people who do not read carefully the attached description go away believing they have seen the actual celestial visitor.

ASTRONOMICAL ANECDOTES

ERRORS OF PTOLEMY'S ALMAGEST

IN MARCH, we discussed briefly the origin of Bayer's material incorporated in his *Uranometria,* and last month something about Ptolemy's star catalogue was set down in this department. The reason for this is that I recently had occasion to glance at Bayer's chart of Centaurus, and was somewhat dismayed to find many of the bright stars very poorly placed. And I am surprised to find a left-handed Orion, with his back toward us; it seems that Bayer wasn't quite consistent in his representations of the constellation figures as seen from the earth, and in the instance of Orion he showed the figure as it would appear from the outside, while the stars are placed as seen from the inside. Or have we made Orion right-handed, and turned him about, since Bayer's day?

The northern constellations of Bayer should be better represented than the southern ones, for Tycho's observations were pretty good. Certainly those given by Ptolemy, whether made by him or Hipparchus or someone else, leave something to be desired. I have had students sketch constellations from the sky, establishing the scale of the large dimensions with a rude cross-staff, and their errors hardly exceed those of the *Almagest,* supposedly derived from careful measurement. I refer here not to the error discussed last month regarding the epoch 138 A.D., for we know that that is not the date for the positions listed.

When all of Ptolemy's longitudes are diminished by 2° 40′, they are reduced to the epoch of Hipparchus, according to Ptolemy's own word and according to the studies of Peters and Knobel. (The small difference of three minutes of arc may be neglected.) Peters and others have computed the positions of the *Almagest* stars for the epoch of Hipparchus (about 130 B.C.) from modern catalogue positions, corrected for precession and proper motion. When these values are compared with the ones derived as above, something like the proper measure of the errors is obtained.

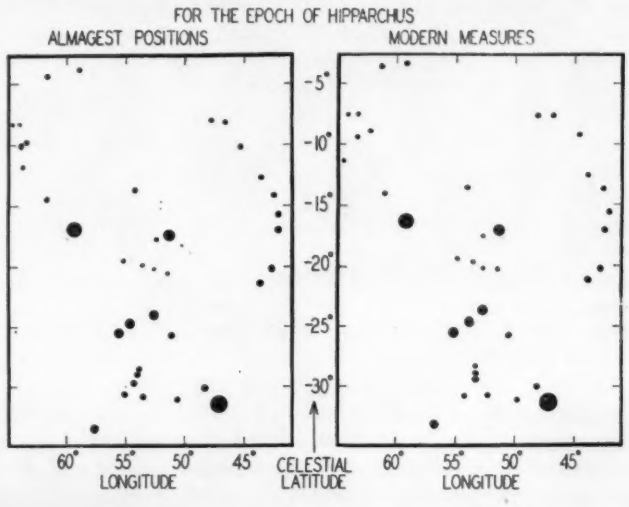
For the zodiacal stars alone, the average errors in celestial longitude range from about 25′ too small to about 13′ too large, depending on the longitude. In celestial latitude, for these same stars, the errors range from 22′ too small to 22′ too large. The errors in both longitude and latitude are periodic, and indicate some maladjustment of the instrument used to measure the positions. A study of this was projected by Peters, but he died before being able to carry it out. Incidentally, the instrument used was an armillary sphere—I have a description of it, and hope to make a model of it.

The errors given above are averages, taken for the stars nearest the ecliptic; hence, they should be least. Some of the largest errors we find near the poles of the ecliptic. If we consider a given constellation—Centaurus, say—we find errors in longitude ranging from 3° 07′ too large to 4° 05′ too small and errors in latitude ranging from 1° 11′ too large to 4° 54′ too small! It was this kind of error that Bayer was forced to copy, more than 14 centuries later. In Centaurus, however, he has corrected some of the errors, perhaps from the observations of the Dutch navigator Pieter Dirchsz Keyser (Latinized as Petrus Theodori), who gave Bayer the material for the south circumpolar groups not observed by Ptolemy or his predecessors.

Even in Canis Minor, where Ptolemy lists only two stars, the longitude difference is wrong by 18′ and the latitude difference by 13′. These values, as do the ones given above, depend of course on the accuracy of the adopted values in the final catalogue of Peters and Knobel. It is possible, but not very likely, that the manuscript written by Ptolemy himself (or Hipparchus) might show smaller errors. There is surprisingly good agreement among the various manuscripts for most of the stars, however, so it is not likely that many of these errors would be diminished if we had the original copy of the catalogue.

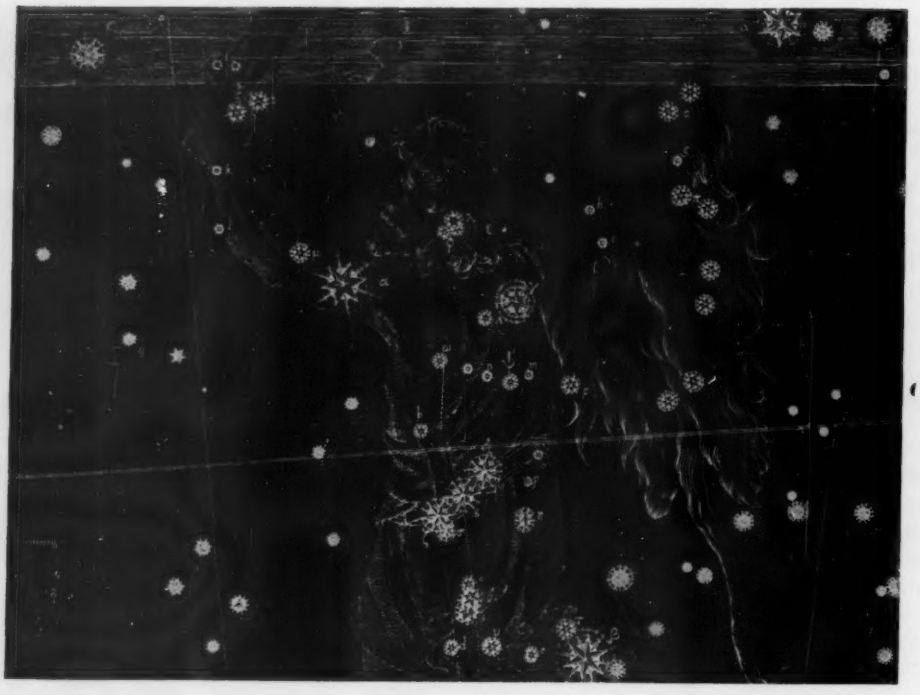
I listed the range of errors by constellation, then arranged the constellations in their rank from worst to best. The worst is Centaurus; the best is Canis Minor. No. 31 on this list (which includes 48 constellations) is Orion; that means that it is one of the better-than-average ones, as far as the errors are concerned. The accompanying diagram compares the Ptolemy positions with the true positions, both for the epoch of Hipparchus; it will give some idea of the kind of error tolerated by Ptolemy.

R. K. M.



The true positions of the stars in Orion in Hipparchus' day may be obtained from modern measures corrected (backward) for proper motion and precession. At the right, these positions are compared with those plotted from the positions given in Ptolemy's catalogue, showing very noticeable errors in several instances.

(Below) A portion of the famous Orion, as he appears in Bayer's "Uranometria."



NEWS NOTES

By Dorrit Hoffleit

SEISMOLOGY IN MEXICO

Mexico is witnessing an unprecedented event in our history: the birth and growth of a volcano. Now there is a cone about 1,000 feet high on what was a flat cornfield only a few months ago. Eruptions have been occurring about 14 times a minute with such noise that conversation three miles away must be shouted to be heard at all. Curiously, all this followed almost immediately upon arrangements between United States scientists and the Mexican government for the establishment of a seismograph station at Tonanzintla, where the new national astrophysical observatory began operation about a year ago. A Benioff vertical seismometer has been obtained through the efforts of the National Research Council and the Geophysical Committee of Harvard University. Tests were made at Weston College.

Early in April, the governor of the state of Puebla and the Mexican ambassador visited the Boston area, including its scientific and military institutions. Discussions of earthquakes and volcanoes played a leading role in the entertainment of the visitors, who brought invitations to some of our own astronomers and physicists to attend a conference in Puebla in May, when the seismometer will be officially installed.

AMERICAN PHILOSOPHICAL SOCIETY

The meetings of the American Philosophical Society, held at Philadelphia April 22nd to 24th, celebrated a pair of 200th anniversaries: the birth of Thomas Jefferson and the anniversary of the proposal by Benjamin Franklin "for forming the American Philosophical Society for promoting useful knowledge among the British Plantations in America."

Thomas Jefferson was president of the society for five consecutive terms. Known best for his political achievements, he had likewise a keen interest in the sciences, including astronomy. For example, his observations of the annular eclipse of 1811 may be found in the *Memoirs* of the American Academy.

DURING THE SIEGE OF LENINGRAD

A report sent by radio to the American Association of Scientific Workers by the Soviet Scientists' Antifascist Committee tells about some of the work carried on by Leningrad astronomers during the siege of the city. Although most scientific research institutions were being evacuated and they were being urged to do likewise, 16 members of the Leningrad Astronomical Institute decided to remain and continue with their observations despite the blockade. Thus they succeeded in preparing a series of almanacs for 1943 for astronomers, geodetic workers, navigators and pilots. Their former astronomical almanac has been enlarged so that it now replaces the nautical almanacs issued in other countries. The plates for the almanacs were taken by plane to Moscow for publication by the Academy of Sciences of the U.S.S.R. Work on the almanacs for 1944 had already begun at the time of this communication, February 12, 1943.

SECTION D VICE-PRESIDENT

Dr. Otto Struve, director of Yerkes and McDonald Observatories, has been elected vice-president of Section D of the American Association for the Advancement of Science. This is the astronomy division of the association.

JAMES RICHARD JEWETT

On March 31st, James R. Jewett, professor emeritus of Arabic at Harvard, amateur astronomer and patron of astronomy, died in Cambridge at the age of 82. It was Prof. Jewett who sponsored the building of Harvard's 24-33-inch Schmidt-type telescope. He also donated his own 9-inch Clark refractor with clock drive and housing to Harvard College Observatory, where it fills a great need in the entertainment and instruction of visitors on open nights, especially on school nights. A close friend of Annie J. Cannon, his last gift has been to aid the publication of the Annie J. Cannon memorial volume which will contain Miss Cannon's work unpublished at the time of her death two years ago.

Prof. Jewett will long be affectionately remembered at Harvard as one of its staunchest friends, and by the association of his name with the work accomplished by means of his telescopes.

"BIRDS OF A FEATHER"

On March 1st, 30 astronomers attended an impromptu get-together at the Science Service building in Washington, D. C., by courtesy of Director Watson Davis. Dr. Harlow Shapley, who had pondered on how many astronomers were in the vicinity of Washington doing war work, found seven colleagues who had gone there directly from Harvard College Observatory. Several others had at some time worked or studied at Harvard. Distinguished among those present were Herbert R. Morgan, of the U. S. Naval Observatory, R. d'E. Atkinson, of the Royal Observatory at Greenwich, Father Paul McNally, director of Georgetown University Observatory, and Wallace J. Eckert, head of the U. S. Nautical Almanac Office.

A GOOD PRECEDENT

Unlike the greater portion of the grounds about the U. S. Naval Observatory, one hillside section has the right kind of soil for gardens, according to experts of the U. S. Department of Agriculture. This section will be divided into small plots for those members of the observatory staff who desire to supplement their ration points with home-grown beets and tomatoes.

The superintendent of the Naval Observatory is setting a good example. Astronomers, look to the grounds about you! Before it is dark enough to start observing, and at sunrise before you go to bed, are fine times for invigorating and profitable gardening!

FOUND: LOTS OF VARIABLES

Eight hundred seventy four new variable stars are reported in seven papers just published in the *Annals* of Harvard College Observatory. The great majority of these stars are fainter than magnitude 13 and brighter than 16 at maximum. They were found as a result of systematic searches in seven comparatively small areas (about 8 x 10 degrees), chiefly in the southern hemisphere of the sky, and *not* in the densest parts of the Milky Way. Of these stars, 339 are members of the nearby system, the Small Magellanic Cloud; the others belong to our own galaxy. A large number of the new variables are presumably over 20,000 light-years distant.

A RAPIDLY EXPANDING ATMOSPHERE

A remarkable star has been observed and studied by Dr. Paul Merrill, of Mt. Wilson Observatory. The star, of the 10th magnitude in the constellation Auriga and known as HD 242257, is classified by Miss Cannon as of spectral class *G*0. This implies that its temperature and average characteristics are much like those of our own sun.

Especial attention was attracted to the star when Mt. Wilson spectra revealed a hydrogen line, Hα, in emission. It is extremely rare for a *G*-type star to show emission lines. Further investigation enabled Dr. Merrill to state that hydrogen in the star's atmosphere is streaming outward at a rate of over 300 miles a second. Such large velocities of expansion are usually observed only in the explosive novae. Dr. Merrill suggests that the forces producing these high-velocity outward motions may be of the same nature as those causing the rapid rise of eruptive prominences from the sun's surface.

Amateur Astronomers

A SAILOR SIGHTS A COMET

By Francis A. Wilmot, *Qm. 3c, U.S.N.R.*

IT WASN'T a periscope wake nor a streak from a Stuka that sent a thrill through me on the starry night of February 25th somewhere on the Atlantic. It was the sudden glimpse of a celestial stranger — a wisp of greenish-white light in the familiar constellation, Ursa Major. Without first verifying it by telescopic aid, I immediately concluded it to be a comet. The telescope (or "long-glass," to be nautical) proved this to be correct, for a tail could be seen, almost six degrees long, pointing toward *x* Ursae Majoris. The nucleus was bright and concentrated, with the coma wrapped around it to a diameter of about 15 minutes. Comparisons with neighboring stars showed the comet to have a magnitude of about 3½.

The officer of the deck notified the captain that "the ship's head astronomer had just discovered a comet." Of course, I myself knew that I could hardly be the original discoverer, for the object was already quite prominent. It must have been known for several weeks. But, with due respect and apologies to Dr. Whipple, for the ship it was known as "Wilmot's comet."

After the first excitement of sighting this comet without *a priori* knowledge of it, I commenced the task of plotting its position and course. However, not having adequate star charts on board, other than the simple navigational star chart, it was necessary to draw one myself. With the ship rolling and pitching, even slightly, with the sea, the task was difficult and required exacting and repeated observations. Nor could it be expected that accuracy could be attained. After observations on several successive nights, I did manage to chart about 40 stars down to the 9th magnitude. Upon the background of these stars I fixed the position of the comet from night to night.

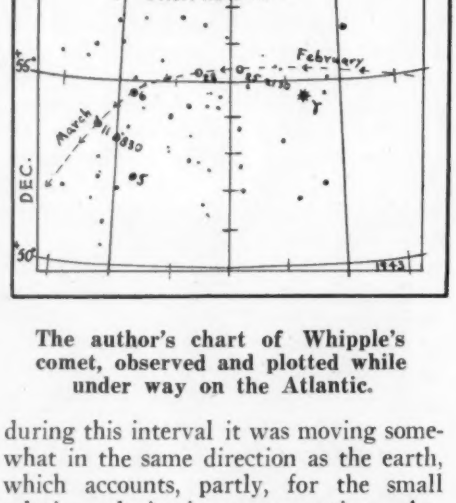
Was it approaching or receding? Had it already passed perihelion? About what was its distance? Well, I next set about to ascertain some of the answers to these questions. It required only two or three days' observation to conclude that the comet was already on its return journey to the depths of space far remote from the sun. The apparent brightness of the comet seemed to be rapidly falling off and at the same time the tail was disappearing. By March 2nd the comet was about as bright as a 4.5-magnitude star and the tail was reduced to about 2½ degrees. At times I seemed to get the impression that there might have been two or three short, stubby tails present.

The comet showed relatively slow proper motion. Using a modified form of a law of average, I calculated that it was moving across our line of sight at the rate of about 1.5 to two miles per second. By averaging the angular motion for every three days, I found the comet changing its position on the celestial sphere by the following amounts:

For	the	first	3	days	26′.25	per	day
"	"	next	"	"	24′.25	"	"
"	"	"	"	"	18′.70	"	"
"	"	"	"	"	20′.00	"	"

Combining the two facts, small proper motion and rapid diminution of apparent brightness, led to the conclusion that the comet's real motion must be mostly along our line of sight, receding from the sun.

A clearer picture of this situation can be realized when the relative positions in space of the comet, earth, and sun, are considered. On March 11th at 08-30 G.C.T., the comet's position was approximately R.A. 12h 24m and Dec. + 53° 50′, at which instant the sun was at S.H.A. 9° 27′ and Dec. — 4° 00′. Thus, the hour circles of these objects were nearly opposite, putting the earth between the two. The comet, therefore, was well outside the earth's orbit. Also,



The author's chart of Whipple's comet, observed and plotted while under way on the Atlantic.

during this interval it was moving somewhat in the same direction as the earth, which accounts, partly, for the small relative velocity in proper motion. Another interesting point to speculate about was the fast disappearance of the comet's tail. From the above explanation, it can be seen that the comet could still have a formidable tail, but due to perspective and the fact that comet tails always point away from the sun, it was seen greatly foreshortened.

This report of course offers no new information, but the whole thing proved rather thrilling, and fills me with some pride. Even under adverse conditions of warfare, an amateur astronomer was able to "discover" the comet, and make difficult observations of it.

AMATEUR ASTRONOMERS ASSOCIATION
New York City

The only meeting of the association this month will be the regular annual meeting on May 19th, when motion pictures will be shown, and the reports of officers and committees heard. There will also be the usual election of members to the Board of Directors, and other business of the society.

Persons interested in membership and the varied program of summer activities should communicate with the secretary, George V. Plachy, American Museum of Natural History, New York City.

NEW YORK AMATEUR WEDS IN TUNISIA

The New York Amateur Astronomers Association and its Optical Division are proud of one of their members, Lt. Bertram Froehly, formerly Bronx bachelor, but now a Tunisian bridegroom. His bride, Lt. Elaine Bost, may some day learn all about telescopes, although right now she is an Army nurse.

Bert, as his friends know him, entered the Air Corps two years ago, reached Tunisia via Georgia and England. His bride followed the same path, and they were married on February 6th. Prior to that, on January 18th, Pilot Froehly was wounded in action, apparently not seriously.

News of these events reached Bert's mother via the War Department and letters from her son, but the world heard the story from Lowell Thomas and read it in New York newspapers.

DETROIT ASTRONOMICAL SOCIETY

The Detroit society, jointly with the Friends of Polish Arts Society, will hold its Copernican celebration on Saturday, May 22nd, at 8 p.m., in the Rackham Educational Memorial auditorium, which seats 1,000 persons. Dr. Everett R. Phelps, of Wayne University, will give the main address. Other speakers will be Dr. W. Carl Rufus, of the University of Michigan, and the Polish consul, who will introduce Prof. Jersy Kaulbersz, former professor of physiology at the University of Kraków, Poland. Prof. Kaulbersz is to speak in both Polish and English. There will be appropriate choruses by Polish nationals in costume. A large number of Detroit citizens of Polish descent are expected to attend.

BURNHAM ASTRONOMICAL SOCIETY

The second annual banquet of the Burnham Astronomical Society was held in the La Salle Hotel, Chicago, on March 24th. Miss Florence Farrar was the vocalist, and Dr. Oliver J. Lee, of Dearborn Observatory, was the guest speaker.

Because the government has taken over the Congress Hotel, the Chicago amateurs have had to move their meeting place to the La Salle Hotel, at La Salle and Madison Streets, where the regular meetings are scheduled for the second and fourth Tuesdays of each month from September to June.

A TRIBUTE TO COPERNICUS

By Maud W. Makemson, *Vassar College Observatory*

THE revolutionary hypothesis of a heliocentric universe gave an impulse to scientific thought that has gathered momentum with the centuries. A seed germinating in unfriendly soil, it thrust slowly upward through the mists of religious bigotry into the pure atmosphere of science, reaching ever toward the eternal stars; and its roots shook the immobile earth to its foundations. The central stem flowered brilliantly in the gravitational astronomy of Newton and reached fruition in the celestial mechanics of the 18th century; but its lesser branches, precise observational and descriptive astronomy, were none the less essential to complete the harmonious whole.

Looking backward over four centuries, some may wonder at the length of time required for the new system to become firmly rooted in the minds of men. Probably no scientific theory was ever so widely discussed or so passionately and bitterly contested by its opponents and defenders over so long a period. More than a century after the publication of *De Revolutionibus,* Father Riccioli wrote a book in which he produced 40 *new* arguments in behalf of the heliocentric theory and 77 against it.

The objections to the theory were tangibly associated with everyday experience; the arguments in its favor were abstract, nebulous, and unsatisfactory. The concept of a moving earth conflicted with common sense. Even today when the earth's rotation has become commonplace, a considerable effort of the imagination is required to visualize the vast and stable earth whirling like a top as it rushes through space

NOVA MVNDANI SYSTEMATIS HYPOTYPOSIS
ab Authore nuper adinuenta, qua tum vetus illa Ptolemaica redundantia & inconcinnitas, tum etiam recens Copernicana in motu Terræ Physica absurditas, excluduntur, omniaq; Apparentiis Cœlestibus apt: sime correspondent.

with the speed of a cannon ball without destroying all life on its surface. Copernicus pictured a kind of "natural" motion which left the exterior of the sphere undisturbed, and his opponents unconvinced. He also pointed out that the far vaster crystal sphere of the fixed stars would be in much graver danger of flying to pieces if it revolved, as they insisted, around the earth.

In the second place, the hypothesis of a stationary sun was at variance with the Bible. What better proof could be found that the sun was habitually in motion than the statement that Joshua commanded the sun to stand still? Thus, Catholic and Protestant alike were necessarily aligned against the new teaching.

The scientists were disturbed by the undoubted fact that no annual oscillation of the stars was observed. Although Bruno had rashly argued for an infinite universe as early as 1585, even Tycho Brahe and Kepler firmly believed that the stars were attached to the surface of a crystalline sphere which marked the boundary of space. If, therefore, the earth describes an orbit about the sun, the stars in a given region of the sky should appear brighter and farther apart when the earth is closest to them, and fainter and more compact six months later when the earth approaches the opposite point of its path. Since no such parallactic motion was observed, Copernicus was compelled to expand the radius of the celestial sphere to such a vast extent that the earth's orbit became immeasurably small in comparison. The vacuous immensity thus interposed between the solar system and the starry heavens was considered extremely wasteful by Tycho Brahe, who remained an opponent of the heliocentric system to the end.

The hypotheses of a rotating and revolving earth are susceptible of exact observational proofs, but such proofs were forced to await the slow development of precise methods of measuring small angles on the celestial sphere and the evolution of a new science of mechanics. The minute effect of stellar parallax was eventually detected by Bessel in 1838 by a method proposed by Galileo; but in the persistent search for this proof through the centuries, astronomy was enriched by a succession of remarkable discoveries which the world assimilated reluctantly. The rotation of the earth on its axis was first

(Above) The diagram shows Tycho's concept of the universe. The earth is at the center, but the planets revolve around the sun—all inside a sphere of stars of limited size.

(Right) Tycho Brahe, the greatest observer before the invention of the telescope.

(Left) Johannes Kepler, Tycho's successor, who formulated the three laws of planetary motion.

demonstrated by the Foucault pendulum experiment in 1851.

Let it not be thought that a theory of the cosmos springs fully perfected from a single mind. The strength and beauty of the Copernican system lay in the fact that it contained the elements of growth and development which will not have reached completion until the origin of solar systems and galaxies and other controversial problems of the present day have been satisfactorily explained in the far distant future. During the first half century after its inception, the theory was generally accepted as a simplified method of calculating the positions of sun, moon, and planets for the annual almanacs which were in demand as the basis for astrological predictions. In 1551, Erasmus Reinhold published his "Prussian Tables," derived by the new system, and they immediately superseded the less accurate Alphonsine Tables based on the Ptolemaic theory. Before the close of the 16th century, however, four men were born who were destined to carry on the work of Copernicus in a manner which would stir men's minds and souls to their depths, and revolutionize their concepts of the universe, although only two of them were ardent defenders of the system. They were Tycho Brahe, born in 1546; Galileo, in 1564; Kepler, 1571; and Descartes, 1596.

Tycho Brahe became the most assiduous observer of the heavens that the world had yet produced. His thoughts were first turned to astronomy by the solar eclipse of 1560. In 1563 he observed a close conjunction of Jupiter and Saturn, and noted that neither the Alphonsine Tables nor those of Reinhold had predicted it exactly, the former being wrong by an entire month, the latter by several days. Although impressed by the necessity for continuous and systematic observations, he was not ready to begin his own great program until 1576.

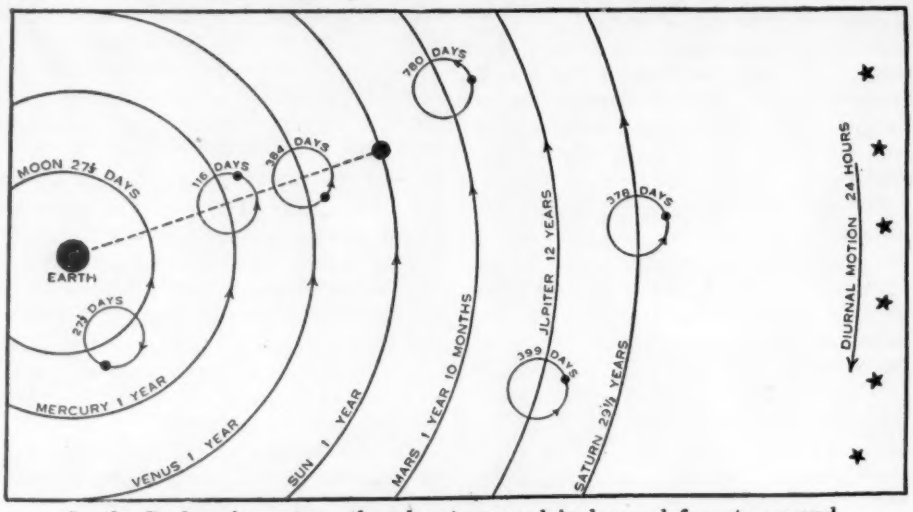
A brilliant new star appeared in Cassiopeia in 1572, which shook Tycho's faith in Aristotle, who had pronounced the heavens unchangeable and incorruptible; for the nova had no measurable parallax and obviously belonged among the fixed stars. Yet the classical teaching held so firm a grasp on the times that Tycho immediately wrote a treatise in which he argued that planets were carried around the earth by revolving crystalline spheres, and comets were generated in the earth's atmosphere.

As if in answer to this challenge, the comet of 1577 trailed brilliantly across the orbits of the inner planets. Tycho measured the parallax, a difficult feat on account of the motion, and concluded that the object was at least three times as far away as the moon and probably beyond the distance of Venus. As the years passed and he followed the bright comets of 1580, 1582, and 1585, his convictions gradually gave way before the evidence of his observations, and he was moved to write a book about these strange visitors from trans-planetary space in which he reasoned that they revolved in orbits about the sun and were not part of the earth's atmosphere. Although he thus abandoned the crystal planetary spheres, Tycho could not reconcile himself to a moving earth. He devised a compromise between Aristotle and Copernicus, in which the planets revolved around the sun, which carried them in an annual orbit about the centrally located earth. Any motion of the inert and heavy earth he dismissed summarily as "contrary to physical principles."

Tycho's observations continued until his death in 1601, seven years before the invention of the telescope. Johannes Kepler, whose almanac for 1595 had gained him an unwarranted reputation as an astrologer and prophet, joined the Danish astronomer at Prague a few months before his death. Kepler has been derided as a mystic, three fourths of whose work was valueless; but his insistent conviction of the divine harmony of the universe, combined with a boundless imagination and a scientific integrity not contented with half measures, enabled him, after years of failure and discouragement, to discover the true laws of planetary motion. Perhaps the dying plea of Tycho Brahe, that his life's work might not have been in vain, gave strength in the darkest hours of Kepler's arduous search.

When Kepler assumed his heritage, he found that Mars stood four or five degrees from the place predicted by the tables of Reinhold. Copernicus once remarked that he would be more than satisfied with his theory if it represented the positions of the planets with an accuracy of 10 minutes of arc, about 1/30 the distance between the Pointers of the Big Dipper. Tycho Brahe's observations with the great mural quadrant attained the surprising accuracy of one or two minutes of arc. So Kepler set out to improve the Copernican system for Mars, until the large discrepancy between observation and prediction was removed. For years he juggled epicycles, equants, and eccentrics of various sizes to attain the desired end. At one point he succeeded in building a structure which reduced the discrepancy to only eight minutes; but steadfastly refusing to accept a result which he considered unworthy of the foundation laid by Tycho, he discarded this system and began once again from the beginning.

At last his perseverance was crowned with success. He saw that the vagaries of Mars could be completely explained within the accuracy of the observations on the assumption that the planet moved in an ellipse with the sun at one focus.



In the Ptolemaic system, the planets moved in large deferents around the earth in their respective sidereal periods, and in small epicycles in their synodic periods, thereby attempting to account for their apparent retrograde motions.

Aristotle's declaration that only the circle was sufficiently perfect to become the path of a celestial body now followed the crystalline planetary spheres into the rubbish heap. Kepler was also able to show mathematically why there are fewer days in the period of the year from autumnal to vernal equinox than there are between the vernal and autumnal equinoxes, that is, why the earth moves fastest in its orbit in midwinter when nearest the sun. This reason was stated in his second law: Every planet moves in such a way that its radius vector sweeps over equal areas in equal intervals of time. The third or harmonic law, relating the squares of the periods of revolution of the planets with the cubes of their mean distances from the sun, led directly to the inverse square law of universal gravitation, formulated by Newton nearly a century later. The *Epitome of Copernican Astronomy,* published by Kepler in 1618, applied his new laws to all the planets and the moon, as well as to the satellites of Jupiter.

In 1609, Galileo turned his rude tele-

scope skyward and discovered an entirely undreamed-of aspect of the universe. To those who were willing to see, the perfection of the cosmos on which Aristotelians had insisted for 2,000 years became no longer tenable. The moon's smooth spherical surface was found to be marred by mountains and pitted by innumerable craters. In the Milky Way, countless stars were visible where there should have been empty space. The glowing Venus revealed waxing and waning phases exactly like those of the moon, proving that it shone only by reflected sunlight and was indeed a satellite of the sun.

Four tiny spheres were seen to perform endless revolutions about Jupiter like children playing around their parent; and the planet continued to pursue its way through the heavens without losing one of them, in spite of the fact that Galileo's opponents pronounced such behavior as "unscriptural." Finally, the sun, in which if anywhere immutability was to be expected, was scarred by dark spots and rotated about an axis!

Even in the face of such overwhelming evidence that the universe was not in conformity with the teachings of Aristotle, the vast majority of scholars still refused to accept the implications. In 1622 Francis Bacon wrote: "Copernicus' scheme is inconvenient; it overloads the earth with a triple motion; it creates a difficulty by separating the sun from the number of the planets with which it has much in common; and the introduction of so much immobility into Nature . . . and making the moon revolve around the earth in an epicycle and some other assumptions of his are the speculations of one who cares not what fictions he introduces into Nature, provided his calculations answer."

Galileo's experiments in mechanics opened a new field for exploration as far-reaching in its potentialities as the sidereal world he had discovered. He established the principle of inertia, later to be restated by Descartes in his laws of nature and embodied by Newton in the first law of motion. Galileo applied it to the moving earth to explain why birds flying through the air, and the atmosphere itself, are not left behind by the planet's motion. Yet, inconsistent as it may now appear, he explained tides as the effect of the earth's rotation, scornfully rejecting Kepler's suggestion that the ocean responded to an influence emanating from the moon.

Descartes taught men to reason and to doubt. Voltaire said of him that he was "born to discover the errors of antiquity and at the same time substitute his own." Apart from his invaluable contributions to mathematics, he advanced indirectly the evolution of the Copernican theory by pointing out that it was possible for the earth to describe an orbit about the sun without actually

René Descartes, after a painting in the Louvre, by Frans Hals.

stirring, if it were swept along by a great current as a motionless ship is borne upon the tide. Thus he reconciled the concept of a moving earth with the Scriptures and by his "vortices" prepared men's minds to accept the law of gravitation. He treated his own system, as he did those of Copernicus and Tycho Brahe, merely as a working hypothesis which "saved the phenomena." His theory was not stated with such exactitude that it could be subjected to experimental tests, yet it was held by many scholars on the Continent until the early part of the 18th century.

Descartes attributed "conductivity" to interplanetary space which he regarded as filled with a "subtle matter," suggestive of the more modern "ether." His proposition that "God . . . always preserves an equal amount of movement in the universe," sounds very much like the modern principle of the conservation of momentum. Other propositions which indicate the extent of his thinking along purely astronomical lines are: that the earth viewed from the heavens would not appear otherwise than as a planet smaller than Jupiter or Saturn; that the sun and fixed stars shine by their own light; that the moon and the planets derive light from the sun; that the moon when it is new is illuminated by the earth; that the hypothesis of Ptolemy does not satisfactorily explain the phenomena; that the hypotheses of Copernicus and Tycho do not differ if they are regarded simply as hypotheses; that the heavens are fluid; that the earth rests in its own heaven, but is nevertheless carried along by it; and many others.

During the 17th century astronomy progressed along a variety of lines. In 1655, Christian Huygens discovered the first satellite of Saturn and announced that, since the quantity of planets and satellites in the solar system had attained the perfect number *twelve,* no others remained to be discovered. Later he established the nature of Saturn's rings and must have seen other satellites without recognizing their character. He invented the pendulum clock in 1656, thus making possible more accurate measures of time, so essential a part of astronomical observations. The micrometer for precise estimates of very small angles in the sky was developed by several observers. French scientists focused attention on the determination of the length of a degree of the earth's meridian in various latitudes and discovered the flattening of the earth at the poles. Hevelius charted the features of the moon.

In the Observatory of Paris, the anti-Copernican Cassini measured the rotations of Jupiter and Mars and discovered new satellites of Saturn; and Roemer established the finite velocity of light from a study of the times of eclipses of Jupiter's moons. These same "Galilean planets" led Borelli to announce in 1666 that the heavenly bodies moved as if acted upon by a central force at right angles to the direction of motion, which prevented them from flying off along the tangent.

In 1677, Edmund Halley observed a transit of Mercury across the disk of the sun and suggested that such a phenomenon could be utilized for determining the distance of the sun from the earth—a proposal which was carried out the following century during a transit of Venus. From a comparison of ancient and modern observations, Halley identified returns of the comet which bears his name, and discovered the secular acceleration in the moon's mean motion and the proper motions of Sirius, Procyon, and Arcturus. From the behavior of Jupiter and Saturn, he suspected the existence of a trans-Saturnian planet, which was verified by the discovery of Uranus 100 years later by William Herschel.

These and many other important discoveries marked the passage of the years. The greatest individual contribution to theory, however, was the work of Isaac Newton. His law of universal gravitation and three laws of motion became the foundation for the celestial mechanics of the 18th and 19th centuries. He introduced the entirely new concept of *mass* as the "quantity of matter," and derived the masses of the sun and of those planets which possess satellites by measuring their attractions against that of the earth for the moon. He showed that the oblate figure of the earth resulted from the mutual gravitation of all its parts, combined with the centrifugal acceleration of its rotation. He predicted a similar oblateness for Jupiter which was later confirmed by Cassini's observations.

The effect of precession of the equinoxes on star places had been recognized

since the time of Hipparchus, and an accurate value had been derived by Copernicus, who also explained the mechanics of the phenomenon. But it remained for Newton to prove that precession followed as the inevitable consequence of the earth's oblateness and rotation, under the attractions of the sun and moon. It has been said of Newton that he explained the "why" of things; but even he regarded the mutual attraction of two bodies, distant from each other in space, as merely a convenient hypothesis for describing an inexplicable phenomenon.

The history of the evolution of the Copernican theory does not end with the triumphs of the 18th century; nor can an adequate account of its far-reaching consequences be presented without sketching the entire history of astronomy to the present day. With each new proof of the validity of the theory, new and grander fields for exploration have been revealed. Its growth has been by a geometrical progression. Only enough has been presented in this small compass to indicate the trend of inquiry, the gradual unfoldment of new concepts. In each of the four centuries since the birth of the Copernican system, there have been pioneers who caught the gleam of something beyond the ever-widening horizon, waiting to be discovered and explained. And so the situation still remains in the 20th century.

ABSTRACTS FROM "THE COPERNICAN THEORY"

(*Continued from page 5*)

Why was a personal visit necessary? The answer is that Copernicus was unwilling to release his book for publication. He communicated his ideas to his personal friends without hesitation, and through this channel they spread. The truth is that he was obsessed by a fear. What reception would be given to a book that subverted concepts established since remote antiquity? What would happen to the author of a treatise that seemed to many persons to contradict the Bible? It was prudent to keep one's peace.

Then in 1539 the eager young professor arrived on the scene. Rheticus was at once enormously impressed by the genius of his host, and realized that failure to publish, or even delay in doing so, meant a serious loss to science. He would take upon himself the responsibility of announcing the new system. If the book raised a storm of hostile criticism, he was prepared to bear the brunt of it. But if, on the contrary, a friendly reception awaited the pronouncement, then the fears of his revered master would be allayed, and his consent could be obtained for immediate publication of his epoch-making treatise.

In pursuance of his plan Rheticus set himself the task of composing a palatable presentation of his master's system. But he employed an entirely different style of writing. He made plentiful use of the attractive artifices of rhetoric. The scientific material was presented, but it was not packed quite so hard. Even the diagrams were omitted by Rheticus, so that his tract did not look like an astronomical treatise.

His book, entitled **First Account of the Revolutions of Nicholas Copernicus,** was so favorably received that a second edition was run off in the following year, 1541. In all probability its success, more than any other single factor, removed Copernicus' fear of adverse criticism and controversy, so that he finally agreed to put his manuscript into the hands of a printer.

Rheticus arranged to have the printing done at Nuremberg, many hundreds of miles from Copernicus' home. Rheticus was, however, unable to see it through because he had accepted a teaching post elsewhere. To carry on the supervision of the printing, he selected a prominent clergyman, Andrew Osiander, who had shown a lively interest in the mathematical sciences.

When the great treatise came off the press, its very first section was a brief Address to the Reader. This declared that no doubt some learned men had been offended by the assertion of the earth's motion; but, after all, astronomical hypotheses need not be true nor even probable.

The result was that readers did not know how to interpret the author's position. The body of the work flatly affirmed the motion of the earth as a physical fact; yet the introductory Address to the Reader said that hypotheses need not be true nor even probable.

More than 60 years passed before the confusion was cleared up. This was done by Kepler, who declared that the author of the Address to the Reader was not Copernicus at all, but Osiander. The final piece of evidence was provided by the edition of Kepler's complete works, the first volume of which appeared in 1858. This contained an essay which had never been printed before, because it was left unfinished by Kepler. It quoted correspondence that passed between Copernicus and Osiander, which made it absolutely certain that Osiander wrote the Address and that Copernicus disagreed basically with Osiander.

Shortly before the publication of this correspondence, the original manuscript of the **Revolutions** in Copernicus' own handwriting came to light. It now became clear for the first time that Osiander had suppressed Copernicus' dignified Introduction to Book I on the value of studying astronomy, and had replaced it by the Address to the Reader, which he himself wrote but from which he withheld his signature.

★ ★

PLANETARIUM NOTES

Sky and Telescope is official bulletin of the Hayden Planetarium in New York City and of the Buhl Planetarium in Pittsburgh, Pa.

★ **THE BUHL PLANETARIUM** presents in *May,* THE BIG DIPPER.

The Big Dipper is the best-known group of stars in the sky. In the Buhl Planetarium's sky show we turn our attention to the many discoveries about the Dipper which have been made in 400 years—since the days of Copernicus, whose quadricentennial we celebrate this month. Our start is with the great astronomer himself—we glimpse what sort of man he was and how his ideas changed this world of ours. He would have liked to know what we know about the Dipper today—that its stars are slowly shifting their apparent positions, so that thousands of years hence they will no longer form a dipper. And five of the seven suns in the Dipper are part of a huge cluster of stars through which our sun and earth are moving. Here, surely, is a story which would have amazed even Copernicus, 400 years ago!

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BEGINNER'S PAGE

VARIABLE STARS—III

BY PERCY W. WITHERELL

AT the beginning of the present century, man was rather pleased with his knowledge of the extent of his galaxy. When its dimensions were compared with the universe's supposed extent 100 years previously, there really was ground for such complacency. There did not seem to be much chance of greatly extending the early 20th-century boundaries, until some brilliant minds noticed the Cepheids, and used the peculiar relation of their magnitudes to their periods to expand our knowledge of the size of the universe to an almost unbelievable extent.

The light curve of a variable star is the plot of observations of its apparent magnitude against the time of the observations. Last month we showed such a curve for an eclipsing binary, in which deep and shallow minima alternated as the stars alternately eclipsed each other. The typical light curve of a Cepheid variable is of quite a different appearance, as the accompanying example shows. From minimum light, the increase in brightness is comparatively rapid, while the fall from maximum is more gradual and somewhat irregular. The minimum is usually of longer duration than the maximum. *Cluster-type* Cepheids are those of extremely short periods—they go through their cycle of phases in less than a day, and in some instances, the light doubles in less than an hour. Zeta Geminorum is representative of a few Cepheids whose rise and fall are of about equal speed.

The visual range of Cepheid luminosities is usually less than one and a half magnitudes, and the variation of those of very short period is often only a few tenths of a magnitude. Usually, Cepheids are redder at minimum than at maximum, changing their spectral class simultaneously with their changes in brightness.

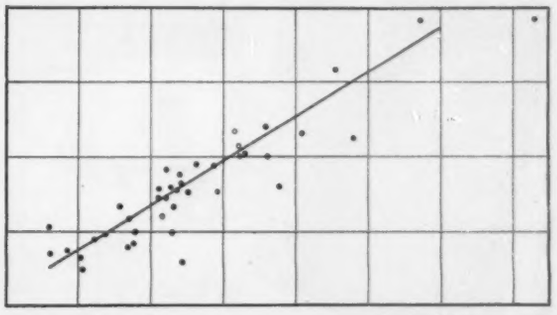
The stars of periods averaging half a day are of spectral class *A*. Cepheids of 4-day periods are about *F*5; those of 8 days, *G*0; and those of over 20 days are about *G*5, but the fluctuation around these means is considerable. The change in spectral class during the variation of its light shows that the star's surface is undergoing changes in temperature (and pressure) which are believed to be the result of alternate contraction and expansion of the star. Confirming this are the periodic Doppler shifts of Cepheid spectra: maximum velocity of approach of the star's surface (violet shift) occurs at or near the time of maximum brightness, while a corresponding maximum velocity of recession (red shift) is observed near the time of minimum light. We shall reserve discussion of the physical explanation of this pulsation of the Cepheids and of other intrinsic variables until we have described the long-period variables in a future article.

At present we are more interested in the relation between the period of a Cepheid and its total luminosity. The real brightnesses of these useful stars show a progressive increase, first discovered in 1912, when Henrietta Leavitt noted a relationship between the apparent magnitudes and the periods of 25 variables in the Small Magellanic Cloud.

These stars all had light curves similar in form to that of the well-known variable, Delta Cephei. Miss Leavitt wrote: "Since the variables [in the Cloud] are probably at nearly the same distance from the earth, their periods are apparently associated with their actual emission of light, as determined by their mass, density, and surface brightness." In other words, the Cloud was assumed to be so distant that all of its stars could be assumed to be about the same distance from us; consequently, the *relative apparent* magnitudes could be considered as giving the *relative absolute* magnitudes. However, since the actual distance of the Cloud was then unknown, the numerical values of the absolute magnitudes could not be determined. The importance of Miss Leavitt's discovery was that she showed Cepheids to have a peculiar characteristic—those of longer period had greater intrinsic luminosities than those of short period.

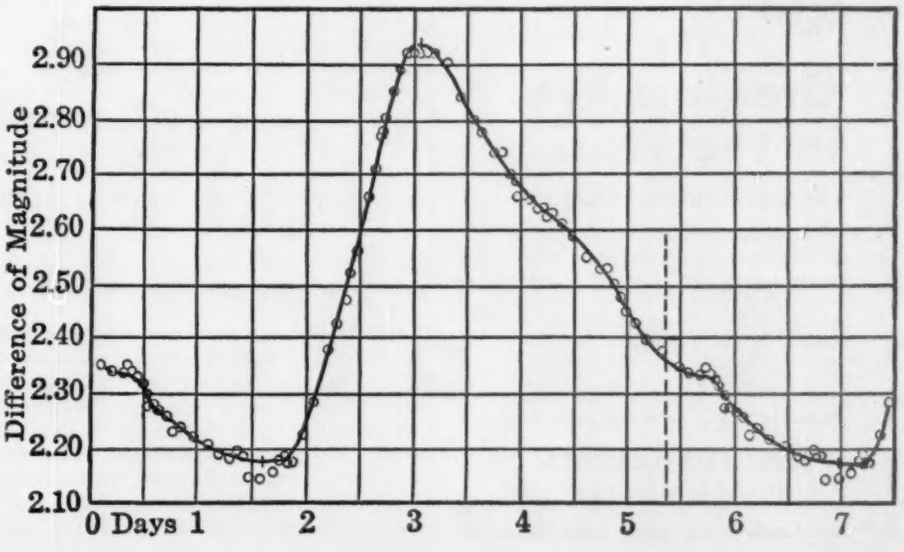
Then, Dr. Harlow Shapley made a series of studies of Cepheids, including those in globular clusters, and in 1918 published the visual *period-luminosity* curve; 11 points on this curve were fixed by our knowledge (by other methods) of the absolute magnitudes of 11 comparatively nearby Cepheids. Later this curve was improved by photographic observations and the adoption of 0.00 as the absolute magnitude of the cluster-type Cepheids.

As a consequence of this remarkable correlation, a Cepheid, wherever it may be in the universe, telegraphs us the clue to its real brightness by the period of its light fluctuations. If a Cepheid is identified as such in some distant cluster or galaxy, and its period can be determined, this period-luminosity relation gives its absolute magnitude. Knowing its absolute magnitude and observing its apparent magnitude, the star's distance can be easily computed. By this means, the distance of the nebula in Andromeda has been set at about 700,000 light-years, and the distances of thousands of other galaxies and clusters have been obtained. The greatest extent of our own galaxy is found to be more than 100,000 light-years, and the Magellanic Clouds are nearly that far away. The uniformity of Cepheid behavior everywhere in the universe seems to be amply confirmed.



(Right) The period-luminosity relation for 40 Cepheids in the Large Magellanic Cloud. Ordinates are median apparent photographic magnitudes from 13 (top) to 17 (bottom). Abscissae are logs of the period in days from 0.25 (left) to 2.0 (close right).

(Below) The light curve of Delta Cephei, by Joel Stebbins, Washburn Observatory.



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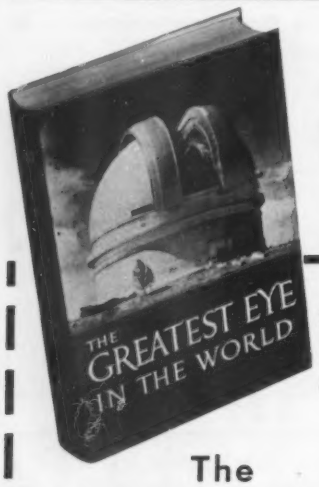

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BOOKS AND THE SKY

ATOMS, STARS AND NEBULAE

Leo Goldberg and Lawrence H. Aller. The Blakiston Company, Philadelphia, 1943. 323 pages. $2.50.

THAT a book can at the same time serve as a textbook in modern astrophysics and as a general book for the interested reader who wants to know the methods and results of modern astronomical spectroscopy may be difficult to believe. But the authors of this elegant volume (the fifth in the Harvard Books on Astronomy) have succeeded in making it fulfill such a dual purpose; like its predecessors in the series, it should have a wide sale and use.

The narrative style is well maintained throughout the book. The technical details are largely summarized in tables liberally sprinkled through the pages; these contain data concerning temperatures, masses, densities, and other characteristics of the stars. The numerous diagrams and graphs aid in visualizing the processes and results expressed in the text, and the many fine halftone reproductions of typical and peculiar spectra make the book useful as a reference work. As in the other Harvard books, photographs of contemporary astronomers add a worthwhile touch.

There is a very definite need for such a book in college courses. In many colleges where interests are not highly technical, outdated textbooks in astrophysics are in use. In others, the instructor's own notes are used, and they are likely to be somewhat heavily weighted in favor of the particular techniques and investigations current at that institution. This book, supplemented with reading from the current literature, would be ideal for use in an introductory course in astrophysics.

As for the general reader, he will find here the answers to his "How do you know?" questions, in form palatable to him, if he really wants to know. Most scientists will agree that the English language is never more precisely used than in science, and he who would read any "popular" science book profitably must read every word, for each one has a definite part to play in the whole story. If this book is read with that thought in mind, it will provide many hours of thorough enjoyment to the serious amateur. It is a very worthy companion to its fellows in the series.

ROY K. MARSHALL
Fels Planetarium

BASIC PRINCIPLES OF WEATHER FORECASTING

Victor P. Starr. Harper and Brothers, New York, 1942. 299 pages. $3.00.

THIS volume with many diagrams and full-page maps is not an elementary book. The reader must be familiar with the modern tools of forecasting before it can be understood; however, the mathematics is kept at a minimum, with the practical aspects emphasized. Outlines for forecasting principles as applied to the 10,000-foot pressure chart and the sea-level pressure distribution are given. The outline includes the semi-permanent pressure formations and intensity of the general circulation, the characteristic features of low and high index type circulations in summer and in winter, and perturbations of the westerlies in middle latitudes. Following this outline, a chapter is devoted to forecasting the actual weather from the field of motion. A short chapter describes the type and size charts and graphs and wind scales used in forecasting.

Separate chapters give examples of forecasting during the four seasons; they include full-page prognostic charts and the actual maps of both sea level and 10,000-foot levels. Another chapter deals with forecasting from local indications of pilot balloon and radiosonde as well as surface observations. Many of the practices recently developed at the University of Chicago are given. The last chapter deals with five-day forecasts. Thirty pages tell of the techniques, data, actual and prognostic charts of the weather; an example and procedure are shown.

An appendix, written by C. G. Rossby, D. Fultz, H. G. Dorsey, and M. Boyden, deals with the forecasting of flow patterns in the free air by the trajectory method; the theory and an example are given.

On the whole, the book is the first of its kind; it deals with the principles from a practical standpoint and follows them up with real examples.

J. H. CONOVER
Blue Hill Meteorological Observatory

A START IN METEOROLOGY

Armand N. Spitz. Norman W. Henley Publishing Company, New York, 1942. 92 pages. $1.50.

AIR NAVIGATION FOR BEGINNERS

Scott G. Lamb. Norman W. Henley Publishing Company, New York, 1942. 103 pages. $1.50.

THE little book by Armand N. Spitz, president of the Rittenhouse Astronomical Society, is a most readable beginner's meteorology text. It is written so that it may be read with pleasure and profit by any 12- to 15-year-old boy or girl interested in learning about the weather. There is, however, no reason why it should not prove equally acceptable to older people. Because of the temporary suspension in the issuing of detailed weather forecasts, many of us have become more weather-conscious than we were in the past. The Spitz book could well become the average citizen's guide for weather forecasting during the emergency. It shows how, with the aid of a simple barometer and thermometer, everyone may start on a career as a weather forecaster.

One may always quibble with an author of a beginner's text about balance and the choice of topics. This reviewer frankly finds little to criticize in this enjoyable and well-written volume. I have two criticisms, but they are not aimed at

the text. The first is that, much as I admire the skill of the author as draftsman, I do not think that the rough drawings scattered in large numbers through the book are suitable. Some of them are very well done (notably the large figures on heights of the clouds and the source regions of air masses), but others are so carelessly drawn as to be annoying to any eager reader. I cannot understand why the author and publishers did not substitute a few good cloud photographs for the smeary cloud drawings that appear now in the book. Secondly, I object to the price, which is about double that for other books of similar size and character.

I cannot become over-excited about the book on air navigation. It bears all the earmarks of having been written by a marine navigator who became interested in air navigation as a side line. The chapter on the compass and its corrections is unnecessarily complex. Piloting and bearings are treated far too much from the point of view of the marine navigator. The treatment of wind problems is confusing. The two brief chapters on celestial navigation are inadequate to the extreme. There is certainly no excuse for introducing the beginner to sidereal time in these days of hour angles! The drawings are neat but uninspired. We need a book on air navigation for beginners that does just what the Spitz book does for meteorology; to this reviewer it seems that the Lamb volume does not do the job.

BART J. BOK
Harvard College Observatory

JULES VERNE—The Biography of an Imagination

George Waltz, Jr. Henry Holt and Company, Inc., New York, 1943. 223 pages. $2.50.

ANY person anticipating a historically accurate biography of Jules Verne will undoubtedly be disappointed in this book. The meager facts available have been supplemented by fiction—as frankly stated by the author—and the feelings of the characters have often been supplied in a manner more suited to autobiography and the romantic novel than to staid history. Anyone expecting a scientific evaluation of Verne's plots is also doomed to disappointment, for here is only a partially critical investigation.

But what of that? Jules Verne was not a scientist; he did not have to be. He was a writer endowed with an imagination, with which he thrilled his readers, describing, among other things, a trip to the center of the earth. Does it matter, seriously, if such a trip is impossible? And is the stimulation to the reader's imagination any less valuable if his ultimate reasoned conviction is that such a trip is impossible? Jules Verne was a popularizer of geography and science: his excellence is as a popularizer, and we are pleased to accept him as such.

Mr. Waltz is not unlike Jules Verne: his book is no more a critique or a biography than Verne's books were geographies or scientific treatises; but like Verne he has written a fictional account which will popularize his basic subject. Myriads love Verne for what he is, asking no more. Myriads of Verne-lovers will enjoy placing Mr. Waltz's imaginative biography on their shelves along with Verne's imaginative science.

LAURENCE J. LAFLEUR
Barnard College

MAN'S PHYSICAL UNIVERSE

Arthur Talbot Bawden. The Macmillan Company, New York, 1943 (Revised Edition). 832 pages. $4.00.

"ONE of the fundamental purposes of **Man's Physical Universe,"** states the author, who is president of Stockton Junior College, "is to enable students to obtain a sufficient background in the field of the physical sciences to enable them to keep up with the developments of science and technology."

In this aim he should succeed admirably, for the book covers in concise units such fields as astronomy, geology, meteorology, electricity, nuclear physics, plant physiology, organic chemistry, and chemotherapy, and all with a minimum of technical terminology.

But it is more than a miscellaneous collection of information. I believe that it was Poincaré who said that a collection of facts is no more a science than a pile of bricks is a house. President Bawden, in his preface, expresses a similar thought:

"A great neurologist showed me how he did his work. In the study of the brain he first prepared very thin slices which he could study in minute detail under the microscope. After making these studies his next great task was to trace the relationships from one slice to another, and not until he did this could he arrive at any meaning in his work.

"Science has done a beautiful job in preparing individual slices of knowledge; but until these slices are fitted together to form a whole again, they will have little meaning. It is the purpose of the survey course [for which this is a text] to try to fit these slices together and to discover a pattern running through all of the sciences that will provide not only intelligible but useful knowledge.

"It has been one of my great concerns," he continues, "that the student be led to develop open, critical and cultural attitudes of mind that will lead him to attempt to use the scientific method in the important problems of life."

To meet this aim, the social implications of the various topics are emphasized. Indeed, the first 50 pages are devoted to the intelligent solution of problems, and the reader is urged to think for himself. Among the suggested topics for discussion are "Should you treat your teacher as an authority?" and "Why is the atmosphere of the lecture platform not favorable to intellectual honesty?"

Since so many of the world's troubles can be traced to unscientific thinking, the importance of this approach is obvious. It is just as vital to the general reader as to the student. While this book is written as a text, it should be of interest and value to a wide group outside of colleges, since it not only summarizes the remarkable achievements of science but indicates as well their broader significance.

JAMES STOKLEY
General Electric Company

THE LITTLE PRINCE

Antoine de Saint-Exupéry. Reynal & Hitchcock, New York, 1943. 91 pages. $2.00.

THIS is a story with as much meaning for adults as for children, and with enough astronomical references, serious, naive, and otherwise, to entrance the star lover. Its unique humor is always pleasant, and its lovely colored drawings give it a singular character. Asteroid B-612, the home of the little prince, boasts three volcanoes. "Two volcanoes are active and the other is extinct. But one never knows." The little prince also had one flower on his planet, which he placed under a glass globe when he started on his journey. The seventh planet he visits is the earth.

C. A. F.

NEW BOOKS RECEIVED

AIRCRAFT MATHEMATICS, *S. A. Walling and J. C. Hill*, 1943, *Macmillan*. 189 pages. $1.25.

Arithmetic, algebra, geometry, trigonometry, in a textbook with the emphasis on these subjects as used in aviation. Of special interest are chapters on Ratio, Relative Velocity, Three Systems of Measuring Angles. Numerous examples and problems make it excellent for the self-taught.

SCIENCE FROM SHIPBOARD, 1943, *Science Service, Washington*. 268 pages. 25c.

A simple and extremely informative manual by various authors covering meteorology, navigation, astronomy, sea and bird life, and other subjects of interest to traveler on transport or pleasure cruise.

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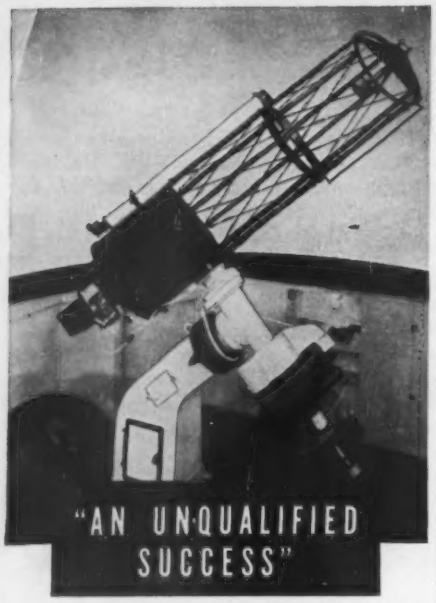

From Volume VIII, No. 6, Publications of The Observatory of The University of Michigan describing the Francis C. McMath Memorial 24-inch Reflecting Telescope, now in operation at the McMath-Hulbert Observatory of the University of Michigan.

"The mirrors were entrusted to The Perkin-Elmer Corporation. Our specifications were exacting, as no part of any surface could depart from the theoretical surface by more than one-tenth of a standard wavelength . . . Perkin-Elmer Corporation completed the primary mirror by conventional methods...It was then tested, pronounced well within the specifications, and found to have an unusually fine surface. The two high magnification secondaries, however, presented real difficulties. McCarthy, of Perkin-Elmer, felt that conventional methods of testing were inadequate and proposed a new method, which he has recently described. The Perkin-Elmer Corporation made up the necessary auxiliary optical equipment, and our two secondaries were figured by the new method, which eliminates the combined testing of primary and secondary. These two mirrors have been an unqualified success, both focal lengths being well within specifications, while the figuring is superb. Exposures for the disk of Jupiter are shorter by a factor of at least twelve when compared with our old 10½-inch telescope."

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GLEANINGS FOR A. T. M.s

Making a Schmidt Correcting Plate

WHY are not more Schmidt cameras constructed by A.T.M.s at the present time? As one who has constructed a number of cameras, from f/0.5 up, I can say that a Schmidt gives more satisfaction to an A.T.M. than any other instrument within his power to make. To raise the objection that the grinding of a Schmidt correcting plate is work for advanced amateurs is "pure bosh"—it is simpler to make than any true surface mirror.

At the present time, of course, one is faced with the material shortage situation with respect to carborundum, but there are several alternative methods for roughing out the primary mirror. One is by sand-blasting (see **The Sky,** October, 1941); another is by turning on a lathe with a carboloy tool bit and a radius rod. However, this article is not concerned with the construction of the primary mirror—that problem is well covered in many sources. I shall confine myself to the preparation of the correcting plate.

1. **Material.** The plate is made of plate glass—about ¼" thick; Vitaglass is best, if it can be procured, because of its high transmission properties in the ultraviolet region—but Crystallex is also very good. If Vitaglass is used, it is wise to examine the piece for striae, which are rare but not always absent. If the sheet is held in front of a completed mirror of any size, any striae present are easily observed by their deflection of light.

The plate should be made as large as the primary mirror, even though the final aperture will be much smaller—the larger size facilitates working, and avoids trouble at the edge.

2. **Preliminary Work.** Before starting the bell-shaped curve on the correcting plate, it should be accurately plane-parallel (0.00025"). Sometimes it is possible to do this by polishing on an HCF full-size lap—if so, press the HCF with a ground flat—but it is usually better to go to fine emery. Measurements should be made with a 10-thousandths micrometer. One side is then polished flat, and we are ready to start the curve on the reverse side.

3. **Grinding the Curve.** The shape of the curve to be ground is determined by the usual equations, obtainable from several sources (see **The Sky,** July and September, 1940), when one has already obtained the other data for the instrument.

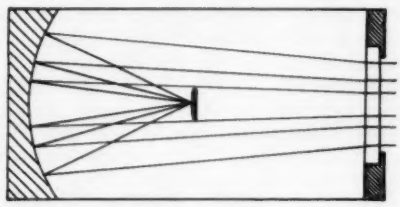
The grinding should be done with a lap made up of ½-inch square, flat unglazed bathroom-floor tiles, mounted on sponge rubber or thick plain rubber backing in the form of a ring. The tiles can be mounted with pitch, which should be boiling. The mean diameter of the ring of tiles should be equal to 7/10 of the diameter of the correcting-plate aperture in the instrument. For instance, if the instrument has an 8-inch mirror of 6-inch focal length, working at f/1.5, this would call for a correcting-plate aperture of four inches; whence 7/10 of 4 is 2.8 inches. It is better to make the ring a little large, so three inches would be the proper mean diameter for the annulus. The width of the annulus should not be greater than a fourth of its mean diameter.

Fine emery (about 303½ or equivalent) is used for the grinding, which is done with the aid of a rubber sink plunger rotated between the hands. About one hour of grinding is required before the first testing.

Incidentally, the used emery can be reclaimed if it is put into a high, narrow tube, filled with water, and allowed to settle. Abrasive is then taken off the top, never using that which sinks to the lower half of the tube.

4. **Testing.** The best method of testing is as follows. This procedure is used for testing both during the grinding and polishing stages:

Construct a small box, containing a small electric lamp, with a frosted glass window for one side. The window is covered with a fine wire screen (the finer the better) and mounted at the focus of the primary mirror, facing the



The paths of light rays which enter a Schmidt camera parallel to its axis.

mirror. The correcting plate is then mounted at the center of curvature. These distances are important, and should be measured very carefully.

The correcting plate is observed from a distance, looking through the plate. The pattern of the screen is easily observed, and any distortion is noted. If the plate is perfectly corrected, there will be no distortion, even at the edges of the plate.

During the grinding stages, the plate is wet with a mixture of kerosene and a light oil, which will render it transparent and it will not dry off too quickly to permit testing. At this time, the observing distance can be from five to 25 feet.

During the polishing stages, get as far away from the camera as possible (up to 150 feet) when testing, and during the final stages, observe the pattern with a small 10x telescope. When no distortion is evident at a distance of 150 feet, the plate will give extremely satisfactory results.

5. **Polishing.** A rotating spindle is necessary for polishing. This can usually be rigged up very simply, as it need not be elaborate. The polishing lap is made up of small disks of pitch on sponge rubber or rubberized cotton belting. The latter is best, as it gives a somewhat firmer backing for the pitch. The disks are made by dropping melted pitch on the backing, taking care that the disks do not overlap or run together. It is also possible to polish with an HCF lap, mounted on sponge rubber, with ⅜-inch

squares ⅛ inch apart. The HCF should be mounted on cork, which in turn is mounted on the sponge rubber. The lap should be circular and about half the size of the correcting plate for zonal finishing, but full size for the first polishing.

6. **Zones.** One of the principal difficulties encountered will be with unsymmetrical zones, and the interpretation of the distortion seen on the test. The following will be helpful:

Barrel-shaped distortion:
- If occurring in the central part of the plate (out to the 7/10 zone), indicates a high zone.
- If occurring near the edge, indicates a low zone.

Pin-cushion distortion:
- If occurring in the central part, indicates a low zone.
- If occurring near the edge, indicates a high zone.

Types of distortion: (a) barrel-shaped or overcorrected; (b) correct; (c) pin-cushion or undercorrected.

7. **Caution.** Be sure not to permit the center of the plate to receive much grinding or polishing. Of course, it must be completely polished, but if a low zone is induced near the center, it means taking down all the rest of the plate to the corresponding level.

ARTHUR DeVANY
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Sauce for the Gander

READERS are asked to send in questions, from which this editor will select the best each month to answer here. The last question is left unanswered, but the reader should be able to find the answer for himself. This month's question came from F. Czyzewski, of South Bend, Ind., and from many others.

Q. What causes sunrises to continue to occur late for nearly two weeks after the winter solstice, December 22nd, while all the increase in the length of the day seems to occur in the afternoon, making the sunsets get later rapidly? And why does the opposite effect hold true after June 22nd, with sunsets continuing to be late until after July 4th?

A. This apparent anomaly results from the two independently variable conditions which affect the time of sunrise and sunset. The better known of these is the variation of day and night lengths resulting from the inclination of the earth's axis. The earth's axis is inclined toward the sun in the summer, away in the winter—the hours of daylight increase from the winter solstice to the summer solstice, but decrease during the other part of the year. If this were the only factor, the time of sunset would advance equally as the time of sunrise receded during the summer and fall, and vice versa during winter and spring. It is this sequence of events which most people take for granted, until they happen to examine a table of sunrise and sunset in an almanac.

The second factor is that of the so-called **equation of time,** which is itself the result of two phenomena—the inclination and the eccentricity of the earth's orbit. This equation of time is familiar to navigators as the difference in the time shown by a watch (mean time) and the time shown by a simple sundial (apparent time), in both cases considering the local time for the place. Readers are referred to standard astronomy and navigation texts for detailed explanations necessary to understanding how the eccentricity and inclination combine to make the equation of time a variable quantity. In other words, the sun does not move uniformly eastward among the stars, and so makes a poor clock. Therefore, the apparent solar day (time from one passage of the sun across the meridian to the next passage) is longest late in December, shortest in March and September, and reaches a secondary peak in June. This moves noon by the clock backward during November, December, and January; the sun reaches the meridian in the forenoon in late September, but is a bit later every day thereafter until it coincides with the clock about December 25th, after which it is late in getting to the meridian for another month and a half. (During this period the equation of time has been changing from its maximum positive to its maximum negative value.)

Consider now the joint effect of both factors. After December 24th, both morning and afternoon are gaining time because the sun is moving northward and the day is getting longer. But because of the change in the equation of time, the afternoon is gaining time at the expense of the morning, and for some days the latter effect is greater than the former. Hence, the sun continues to rise later in the morning, although it sets so much later in the afternoon that the length of the morning and afternoon combined increases.

A similar explanation can be applied to the situation at the time of the summer solstice.

Q. What are the Widmanstätten lines in a meteorite?

L. J. LAFLEUR

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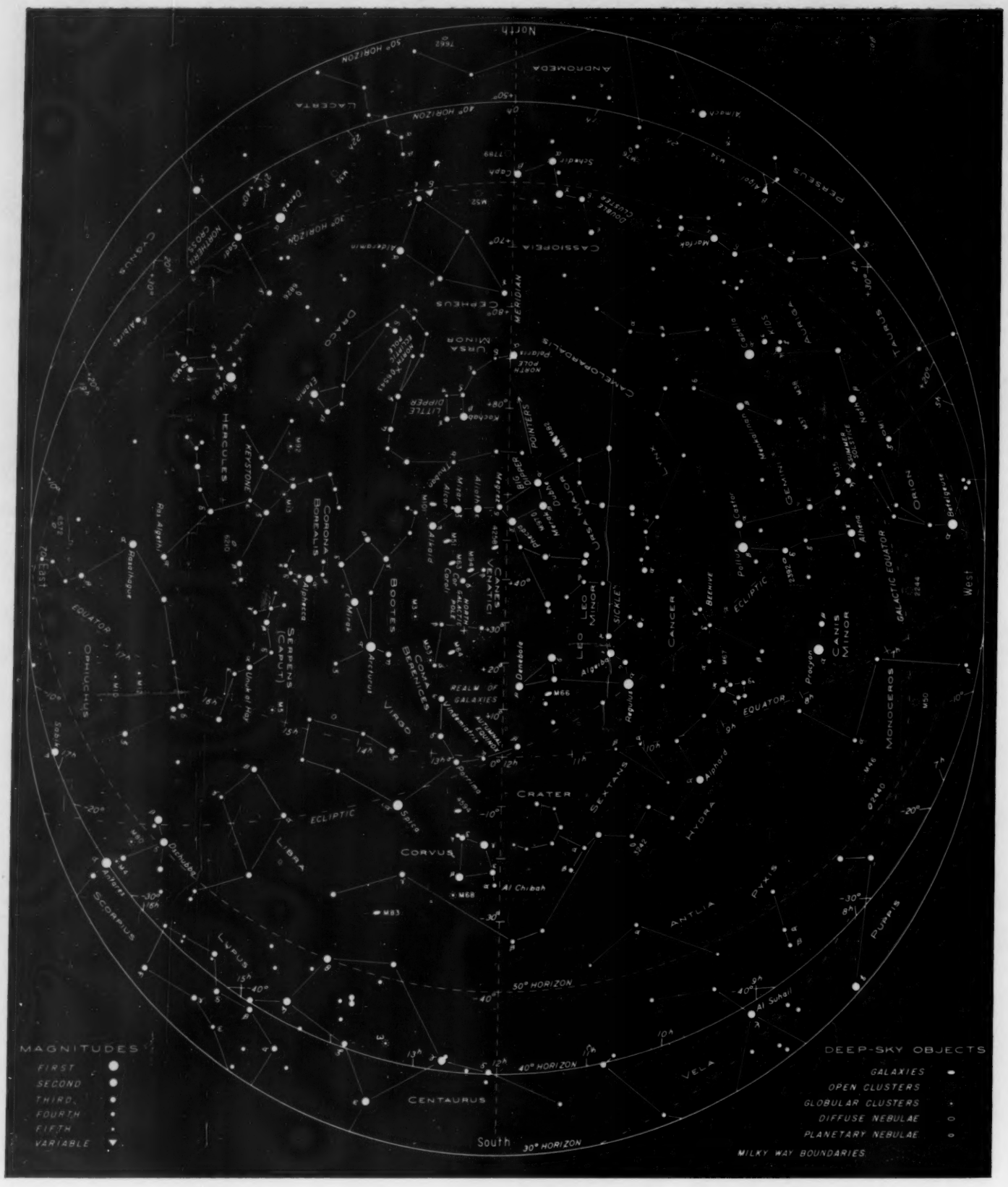


DEEP-SKY WONDERS

THIS month finds the following objects in good position for observation with moderate-sized telescopes. Descriptions are from Norton's **Star Atlas.**

Centaurus. Omega, a beautiful globular cluster, easily visible to the naked eye, "like a tailless comet, nearly 4th magnitude." It is 30′ in diameter, and contains thousands of 12th- and 15th-magnitude stars. Its position is 13h 23.7m, −47° 3′.

Ursa Major. M97, 11h 11.8m, +55° 17′; the Owl nebula, a large faint planetary, 3′ in diameter. Large aperture, low power, and a clear night are required for a good view.

Coma Berenices. M64, 12h 54.3m, + 21° 57′; the Black-eye nebula, a bright oval, with a dark central area of absorbing matter, visible in large telescopes. N.G.C. 4565, 12h 33.9m, + 26° 16′; the largest edgewise spiral, 15′ x 1′, with a bright center.

THE *STARS* FOR MAY

as seen from latitudes 30° to 50° north, at 10 p.m. and 9 p.m. on the 7th and 23rd of the month, respectively. The 40° north horizon is a solid circle; the others are circles, too, but dashed in part. When facing north, hold "North" at the bottom, and similarly for other directions. This is a stereographic projection, in which the flattened appearance of the sky itself is closely reproduced, without distortion.

AIR AND SEA AND SKY

A department devoted to wartime subjects related to astronomy, such as aerial and celestial navigation, and meteorology.

Navigating in the Air — II

MODERN celestial navigation is based almost entirely upon the line of position, discovered by Capt. Sumner in 1838. In this magazine the method of working up a fix using such lines was discussed by several writers recently, but it is worth our reviewing the theoretical principles involved.

We must begin by making an assumption familiar to all students of astronomy who are acquainted with the concept of the celestial sphere: that light rays coming to us from celestial bodies are parallel. Most heavenly bodies are so far distant that for practically all purposes this is true. For members of the solar system, particularly the moon, it is not true, and certain corrections must be made. These are usually applied to our sextant observations and make it possible, in considering its circle of position, to treat the moon or a planet as if it were as distant as a star.

In the accompanying diagram, the center of the earth is at O. Let S be a star or another celestial object, and P that point on the earth's surface at which the star is directly overhead. (For purposes of explanation, we may assume the zenith to lie along a line from the center of the earth through the observer's position on the surface.)

A, B, and C are the positions of various observers on the earth, and Z^1, Z^2, and Z^3, their respective zeniths. According to our assumption, the star will appear in the directions of S^1, S^2, and S^3, respectively, these directions being parallel because all the light rays coming from the star are parallel, wherever they may strike the earth.

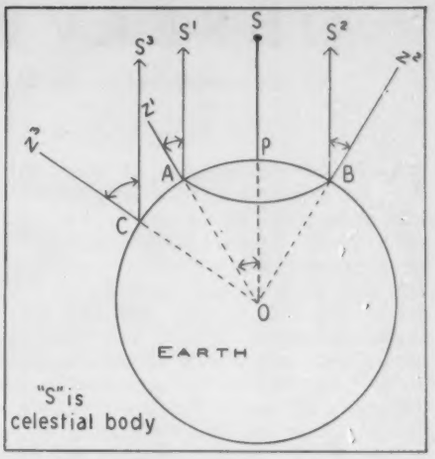
The angle Z^1AS^1 is the zenith distance of the star as seen from A, that is, the angular distance of the star from Z^1. But this angle is equal to the angle AOP, the angle at the center of the earth between P and A. In other words, the angular distance over the surface of the earth from the observer to the point where the body is overhead is equal to the zenith distance of the body. It is obvious that there must be other points on the earth where the zenith distance of S will be equal to this same quantity, such as at B.

The angle BOP is equal to AOP, so a circle with P at its center can be drawn through A and B and all the other points for which S has the same zenith distance. The radius of this circle is equal to the arc subtended at O by the observed zenith distances. But for an observer at C, which is farther from P, the zenith distance will be correspondingly greater, while for an observer who is nearer to P, the zenith distance will be less.

The zenith distance of an object is the complement of its altitude: 90 degrees minus the altitude. Since it is more practicable to observe the altitude than the zenith distance, the navigator makes such an observation to find the radius of the circle of position on which his craft lies, the center of that circle being the point where the body observed is overhead.

The position of this point on the earth, known as the substellar, subsolar, or sublunar point, as the case may be, is easily determined. Its latitude is equal to the body's declination. Its longitude is equal to the body's Greenwich hour angle. If the Greenwich time is known, these values may be easily found from an almanac. It is for this reason that we must time our sights accurately, for the rotation of the earth changes the position of the center of the circle of position constantly, and at a rate generally faster than that at which we are moving ourselves.

If we were to find the position of the substellar point on a globe, we could, using a pair of dividers, describe the circle of position. A similar observation of another body taken at the same time would yield another circle, intersecting the first at two points. Our position would be at one of these intersections. In practice, however, these circles are not actually drawn at all, nor is a globe used, except in certain methods of less practicability and accuracy. A small arc of each circle, represented by a short straight line, is plotted upon a large-scale chart. These

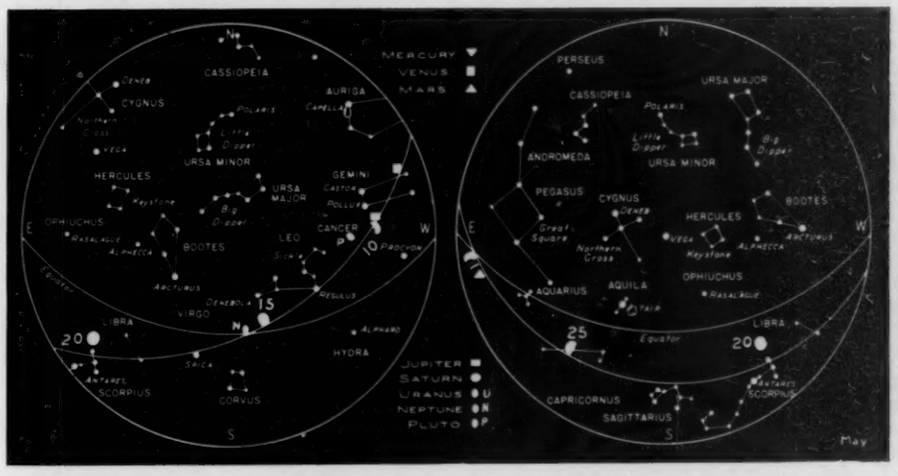


are the lines of position, and their intersection gives our fix.

It is interesting to note that if the azimuth of the body could be determined with an accuracy comparable to that with which the altitude is measured, the position of the craft could be found from one observation alone. For example, if we observe a body due south at an altitude of 40 degrees, its zenith distance would be 50 degrees, and we would be 50 degrees to the north of the substellar point. But in this case, the direction "due south" could not be observed as being definitely and exactly of that value. Therefore, we draw the line of position perpendicular to due south, but we do not know our position along that line until we have found another line intersecting it at an appreciable angle.

S. S.

THE MOON AND PLANETS IN THE EVENING AND MORNING SKIES



In mid-northern latitudes, the sky appears as at the right at 4:30 a.m. on the 7th of the month, and at 3:30 a.m. on the 23rd. At the left is the sky for 10:30 p.m. on the 7th and for 9:30 p.m. on the 23rd. The moon's position is marked for each five days by symbols which show roughly its phase. Each planet has a special symbol, and is located for the middle of the month, unless otherwise marked. The sun is not shown, although at times it may be above the indicated horizon. Only the brightest stars are included, and the more conspicuous constellations.

Mercury will be too close to the sun for observation except for the first two or three days of the month.

Venus, in Taurus and Gemini, will be 20′ north of Epsilon Geminorum, magnitude 3.2, on May 19th. The planet's magnitude will be −3.7 at the end of the month.

Mars, in Aquarius and Pisces, will arrive at the vernal equinox at the end of the month. Its magnitude of 0.8 will make it about as bright as Altair.

Jupiter will be in Gemini.

Saturn and **Uranus,** in Taurus, are too close to the sun for favorable observation.

Neptune. See chart in the March issue.

OBSERVER'S PAGE

All times mentioned on the Observer's Page are Eastern war time.

Regulus in Occultation and Conjunction

DURING the evening of May 12th, the brightest star in Leo, Regulus, will be occulted by the moon. Out of a series of 17 Regulus occultations going on at present, this event is the only one that may be observed from any part of the United States. (See **Sky and Telescope,** December, 1942.) The southern states, from the Rocky Mountains eastward, may witness the occultation, although in the more western states daylight will interfere to a certain degree.

The path of the moon during that evening will be in a southeasterly direction—slightly more than 15 degrees south of due east. As the moon moves over our Pacific coast area, the occultation would be observed from Mexico to Canada were it not for daylight. Regulus, magnitude 1.3, is practically unobservable when the sun is above the horizon. We find in the **American Ephemeris** that at standard station Long. 120° W., Lat. +36°, which is midway between San Francisco and Los Angeles, the occultation will begin at 6:04.8 p.m. P. W. T., or about two hours before sunset. At that location the event will occur east of the local meridian (the negative type), and the star will emerge at 7:37.9 p.m., but still in daylight.

As the moon moves toward the east, observers in the middle of Arizona and Utah will see it intercept the light from Regulus when the star is close to the meridian. Sunlight and twilight will still interfere, but the emersion should be visible. From there to the Atlantic coast, the occultation will be of the positive type, that is, west of the local meridian.

Since the path of the moon is southeasterly, it will have moved so far south by the time it reaches the Mississippi valley that only the southern half of the central states can witness the occultation. At standard station Long. 91° W., Lat. +40°, which is near Quincy, Ill., there will be a short occultation just below the northern limb of the moon: immersion at 9:22.0 p.m. C.W.T., P. 55°; emersion at 10:03.6 p.m., P. 356°.

At Chicago, the star and the moon will be in conjunction in right ascension at 10:04 p.m. C.W.T., but there will be no occultation. The star will be about 2′ north of the moon's edge, although, as shown in the diagram, prior to the conjunction it will have passed **very close** to the northern limb.

Nineteen minutes after the Chicago conjunction, a similar event will be observed from Washington, D. C., with Regulus about twice as far from the moon. And one minute later, at 11:24 p.m. E.W.T., New York observers will see Regulus about 6′ north of the moon. The position angle of the moon's axis will be 22°, so the conjunctions will be in line with the crater Strabo.

These events all demonstrate the trend of the moon toward the southeast, and if we visualize the "shadow" of the moon "cast" by the light from the star to have a diameter of 2,160 miles, we can understand why the southern tier of states may see the occultation. To give observers in those states a very approximate idea of the times to watch the event from their respective local stations, I have computed the data for Fort Worth, Tex., and Miami, Fla., using only approximate latitudes and longitudes as scaled from an atlas map—a procedure accurate enough for this occasion and purpose.

	Ft. Worth (C.W.T.)	Miami (E.W.T.)
Immersion	9:00.9 p.m.	10:49.3 p.m.
Position Angle	93°.5	85°
Emersion	10:24.7 p.m.	11:56.0 p.m.
Position Angle	319°.5	327°.5

The star will disappear for 84 minutes at Fort Worth. Immersion at Miami will occur 35 minutes before emersion at the Texas city. From these times, a resident of a neighboring state should be able to interpolate, with a fair degree of accuracy, for the times at his location. In that vast area, there are bound to be some clear skies, and well-planned observations to time the occultation should be made. The war has reduced the number of occultation observations to an alarming extent; the Occultation Committee of the A.A.V.S.O. will welcome reports, which should be sent to Dr. Alice H. Farnsworth, Mt. Holyoke College, South Hadley, Mass.

The observer's exact latitude and longitude are essential and can probably be ascertained by consulting maps at the local county clerk's office. A reading glass will help read the second-hand dial on an ordinary watch so the time may be determined to the half second. Careful checking of the watch is necessary; a time signal lasting one second is broadcast hourly on the Red, Blue, and Mutual networks; the start of the signal is the beginning of the hour.

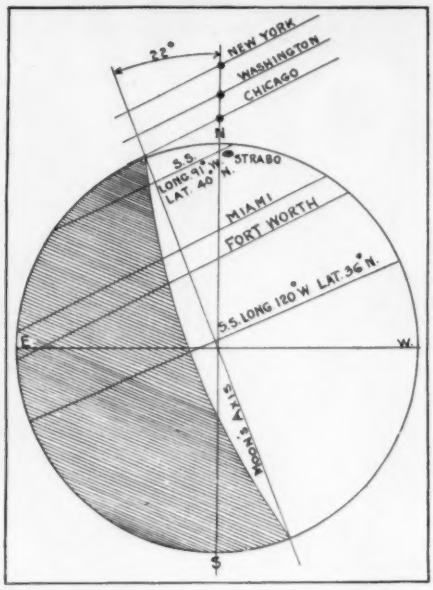
OCCULTATIONS — MAY, 1943

Local station, lat. 40° 48′.6, long. 4^h 55.8^m west.

Date	Mag.	Name	Immersion	P.*	Emersion		P.*
May 7	7.1	BD + 18° 1040	10:08.7 p.m.	121°			
11	5.6	Pi Cancri	7:22.7 p.m.	140°	8:40.8 p.m.		262°
16	5.9	65 Virginis	11:26.7 p.m.	133°	0:44.1 a.m.	(17)	282°
17	5.8	66 Virginis	0:30.0 a.m.	150°	1:33.0 a.m.		261°
22	5.4	15 Sagittarii	1:42.4 a.m.	120°	2:53.5 a.m.		251°
22	6.0	16 Sagittarii	1:49.8 a.m.	41°	2:36.9 a.m.		331°
24	5.5	Sigma Capricorni	1:30.6 a.m.	127°	2:23.0 a.m.		224°
26	5.6	42 Aquarii	1:57.2 a.m.	105°	2:53.5 a.m.		228°

*P is the position angle of the point of contact on the moon's disk measured eastward from the north point.

By Jesse A. Fitzpatrick



PHASES OF THE MOON

New moon.....May 4, 5:43 a.m.
First quarter.....May 12, 5:52 a.m.
Full moon.....May 19, 5:13 p.m.
Last quarter.....May 26, 9:33 a.m.

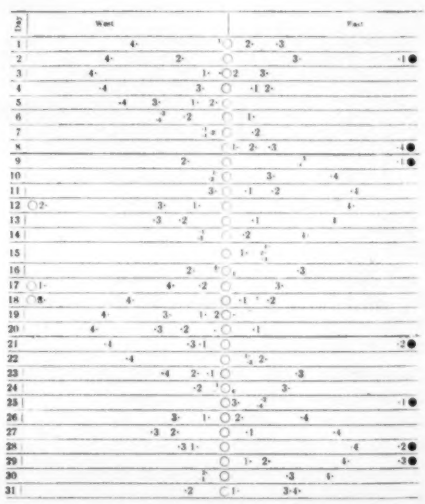
ANOTHER BRIGHT AURORA

On Monday evening, March 29th, a brilliant auroral display was observed from the northeastern part of the United States. A bright, green arch persisted throughout the evening, with variations in form and color, and at one time rays reaching the zenith almost gathered to form a corona.

JUPITER'S SATELLITES

On May 4th, the four principal moons will be west of the planet. On the 7th, after 11:37.2 p.m., and throughout the evening of May 14th, they will be on the east side.

Jupiter's four bright moons have the positions shown below at 11:15 p.m. E. W. T., the day preceding the date shown. The motion of each satellite is from the dot to the number designating it. Transits of satellites over Jupiter's disk are shown by open circles at the left, and eclipses and occultations by black disks at the right. From the American Ephemeris.



THE HARVARD BOOKS ON ASTRONOMY

Edited by HARLOW SHAPLEY and BART J. BOK
Harvard College Observatory

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A concise, well-illustrated account of the planets and their atmospheres, with a discussion of the possibilities of life outside the earth, is presented in non-technical language. The reader is carried in his imagination below the clouds on Venus, Mars and the giant planets, into the depths of the earth and to the rough and airless surfaces on the Moon, Mercury and Pluto. A planet finder and star chart are included. *By Fred L. Whipple.*

The Milky Way

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This book presents in semi-popular form a summary of our present knowledge of the Milky Way and explains some of the problems which remain to be solved. The dust and gas in the vast spaces between the stars, the compositions and dimensions of star clusters, the appearance of our galaxy to an observer in the Andromeda nebula, and the problems related to the past and future of our galaxy are discussed. Two large scale photographic maps of the Milky Way and portraits of our leading scientists in the field are included. *By Bart J. Bok and Priscilla F. Bok.*

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226 Pages
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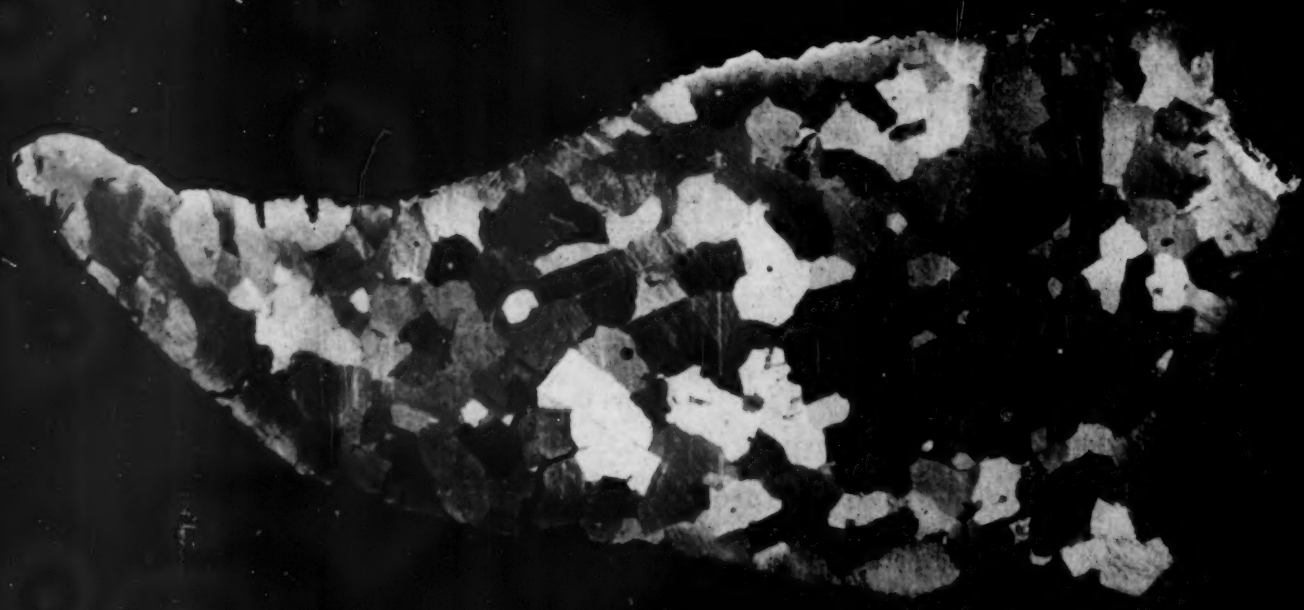
(1941)

The Cepheid variables provide not only information about the deep interiors of stars but they also prove to be useful yardsticks for sounding the universe. This book introduces the reader to the technique of observation and then proceeds to analyze the present state of our knowledge of variable stars. A list of brighter variables, a Julian calendar and other useful tables are included. *By Leon Campbell and Luigi Jacchia.*

Philadelphia, Pa.

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